A Review of the Nitrate Problems in the Ground Waters of the Santa Ana Region and Their Relationship to High Density Developments on Septic Tank-Subsurface Disposal Systems

California Regional Water Quality Control Board*
Santa Ana Region

September 8, 1989

A REVIEW OF THE NITRATE PROBLEMS IN THE GROUNDWATERS OF THE SANTA ANA REGION AND THEIR RELATIONSHIP TO HIGH DENSITY DEVELOPMENTS ON SEPTIC TANK-SUBSRFACE DISPOSAL SYSTEMS

California Regional Water Quality Control Board
Santa Ana Region

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Special thanks to all those who have helped us with the preparation of this report.

California Regional Water Quality Control Board
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ITEM: 5 b.

SUBJECT: A Review of the Nitrate Problems in the Ground Waters of the Santa Ana Region and Their Relationship to High Density Developments on Septic Tank-Subsurface Disposal Systems

DISCUSSION: See Enclosed Report

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1.0 EXECUTIVE SUMMARY

The Santa Ana Region is characterized by dramatic population growth; in fact, the Region experienced the largest population growth nationwide during 1988. Most of this population is concentrated in urban areas, where high density residential developments on small lots are typical. Due to the lack of sanitary sewers in many areas where rapid growth is occurring, many of these high density developments utilize on-site septic tank disposal systems for sewage disposal. Such high density use of septic tank systems can be expected to cause or exacerbate ground water quality problems.

The ground water resources of the Santa Ana Region are among the most significant in Southern California and constitute approximately 60% of the Region's total water supply. There is mounting evidence that much of this resource is adversely affected or threatened by high concentrations of nitrate. Concentrations of nitrate at or above 45 mg/l as nitrate (or 10 mg/l nitrate as nitrogen) necessitate the removal of domestic supply wells from service or blending with better quality water to assure that public health is protected. Sources of nitrate input to ground (and surface) waters include agricultural activities (including dairy operations), municipal sewage treatment plant effluents, and urban runoff. However, septic systems are one of the most significant sources of nitrates; the buildup of nitrate in ground waters is potentially one of the most significant long-term consequences of onsite sewage disposal.

Under certain conditions, onsite subsurface disposal systems can function effectively to treat and dispose of human and household wastes without causing bacterial contamination of ground or surface waters. Soil characteristics must be correct and the systems must be properly engineered, installed and maintained. But standard siting and design criteria do not address the loading of nitrate to ground water by septic tank effluents. **Nor do these criteria consider the cumulative impacts of multiple systems. The most important factor influencing contamination of ground water by nitrate as a result of septic system use is the density of the systems in an area.**

High density septic system use, such as is occurring or is proposed to occur in the Santa Ana Region, will cause or aggravate existing nitrate problems in the ground waters of the Region. The high density of these systems has two effects: first, the relative volume of ground water available for dilution of septic tank effluents is decreased; and second, the cumulative volume of wastewater discharged from multiple systems may alter local ground water levels to the point that the performance of individual systems or the degree of treatment provided by the soil system is adversely affected. As might be expected, the generally recommended methods of mitigating the impacts of high density septic system use are the elimination of the discharges, such as by sewering, and the establishment of maximum allowable densities (or minimum lot sizes).

Using data applicable to the Santa Ana Region, staff has performed detailed calculations to determine the minimum lot size which should be required for septic system use in order to prevent water quality impacts. Based on these calculations, staff recommends that a minimum lot size requirement of 0.5 acre be specified for new septic system use in the Santa Ana Region. It must be emphasized that this requirement would <u>not</u> affect in any way the lot size criterion for continuing exemptions for septic system use in prohibition areas (minimum lot size of one acre); nor would this recommended minimum lot size requirement preclude the possibility of more stringent lot size requirements in specific areas, if determined necessary to protect water quality.

In accordance with Sections 13225 and 13240 of the Water Code, the Regional Board is empowered to develop and amend as necessary a Basin Plan, prescribing the measures necessary to protect water quality in the Region. Board staff proposes the amendment of the Basin Plan for the Santa Ana Region to incorporate the recommended minimum lot size requirement for subsurface disposal system use.

2.0 HIGH DENSITY DEVELOPMENTS ON SEPTIC SYSTEMS - NITRATE PROBLEMS IN GROUND WATERS OF THE SANTA ANA REGION

2.1 High Density Septic System Use

Under certain conditions, onsite subsurface disposal systems can function effectively to treat and dispose of human and household wastes without causing ground (or surface) water quality problems. The septic systems must be properly engineered, installed and maintained, and the soil characteristics must be correct. But the most important factor influencing ground water contamination from septic system use is the density of the systems in an area.

In rural settings, the use of onsite subsurface sewage disposal systems has long been recognized as one of the most effective means of meeting sanitary waste disposal needs. In these sparsely populated areas, the low density of septic system use, combined with the recharge of precipitation which is possible in the large available open spaces, minimize the potential ground water quality impacts associated with septic systems.

In contrast, high density septic system use, such as is typical of unsewered urban areas, can be <u>expected</u> to cause or exacerbate ground water quality problems (2,3,4,12,13). These problems are likely to result, in turn, in adverse effects on the suitability of ground water for various purposes, including municipal supply, and can cause actual or threatened impacts on public health. The effects of high density developments on septic systems are two-fold. First, as the density of septic systems increases, the relative volume of recharge waters and ground water available for dilution of the septic tank effluent declines. The likelihood of contamination by nitrates or other constituents of septic tank effluent therefore increases. Second, under certain conditions, the total volume of wastewater discharged from a large number of systems may alter local ground water levels to the point that the performance of individual systems, or the degree of treatment provided by the soil system, is adversely affected. The effects of high density septic systems in urban areas are exacerbated by the significant reduction in the recharge of precipitation which is caused by extensive development of impervious surfaces.

The Santa Ana Region experienced the largest population growth nationwide during 1988. Most of this population is concentrated in the urban areas of the Region. In these areas, high density developments on small lots are quite common in order to economize on land costs and to facilitate the provision of other services. Due to the lack of sanitary sewers in many areas where rapid growth is occurring, many of these new, high density developments utilize on-site septic tank systems for sewage disposal. In the Fontana area, for example, approximately 25% of the population uses on-site septic systems. According to records in the Regional Board files, approximately 90 % of the septic system approvals in the Fontana/Bloomington area of San Bernardino County during 1988 were for systems on small lots (approximately 7000 square feet). Such high density developments on septic systems can be expected to adversely impact ground water quality in the various ground water subbasins of the Region.

2.2 Nitrate Problems Caused by Septic Systems

The buildup of nitrate in ground water is potentially one of the most significant long-term consequences of onsite sewage disposal. In California, discharges from subsurface systems are one of two primary causes of nitrate contamination of ground water (the other is agricultural operations)(7,17). The nitrate loading unit factors (pounds of nitrate per acre per year) used in ground water models (26) to determine the quality impacts associated with various types of land use include a factor for septic systems (Table 1). It is noteworthy that this septic system nitrate factor is second only to dairies and feedlots.

Nitrate buildup in ground waters used for municipal supply has potentially serious public health implications. Both the U.S. Environmental Protection Agency and the California Department of Health Services have adopted a primary drinking water standard (MCL) for nitrate of 45 mg/l as nitrate. (This is equivalent to 10 mg/l as nitrate-nitrogen). This drinking water standard was established to prevent methemoglobinemia, or "blue baby syndrome", a fatal condition in 5% of the infants affected. Ingested nitrate is reduced to nitrite in the stomach of infants. The nitrite then combines with blood hemoglobin to form methemoglobin, which has reduced capacity to carry oxygen. Concentrations of methemoglobin in excess of 70% result in asphyxia (30). Recent studies have also indicated some link between increased incidence of cancer and high nitrate in drinking water (30,31,32,33). In addition, some relationship has been established between the intake of nitrate and teratogenesis (the deformation of the fetus in the first trimester of pregnancy) and mutagenesis (actual damage of genetic material which can be passed to succeeding generations) (34).

TABLE 1

NITRATE UNIT LOADING FACTORS USED IN BASIN PLANNING PROCEDURE

Landuse	Unit Factors (Pounds/acre/year)
1. Non-irrigated Field Crops and Pasture	263
2. Irrigated Field Crops and Pasture	263
3. Irrigated Vineyards	144
4. Non-irrigated Vineyards	144
5. Dairies and Feedlots	1261
6. Urban Residential, Commercial, and Industrial	
a. Septic System Use	407
b. Outside Use	176
7. Impervious Surface	0
8. Native Vegetation	0

Sources:
1. Water Resources Engineers (1970)
2. Albert Webb Associates (1974)
3. James M. Montgomery Engineers (1989)

Septic tank effluent typically contains 35-100 mg/l total nitrogen, primarily in the form of ammonia (as ammonium ion) (35). Almost all of this ammonia is converted (nitrified) to nitrate in the unsaturated zone in well-aerated soil. Once formed, nitrate is relatively stable and mobile, and it tends to pass easily through soils , together with percolating effluent and other recharge waters, to ground water (12). The only active mechanism for lowering the nitrate content of septic tank effluent is dilution with better quality water. The amount of water available for dilution is related to two factors, both of which were mentioned previously: precipitation, and the density of the subsurface disposal systems in the area. Because of the hot and dry climate of most of the Region, and because of increasing expanses of impervious areas which limit recharge, there is very little dilution of septic tank effluent by precipitation in the Region in most months of the year. As noted above, with the proliferation of high density developments on septic systems in the Region, the relative amount of ground water available for dilution of septic tank effluent declines.

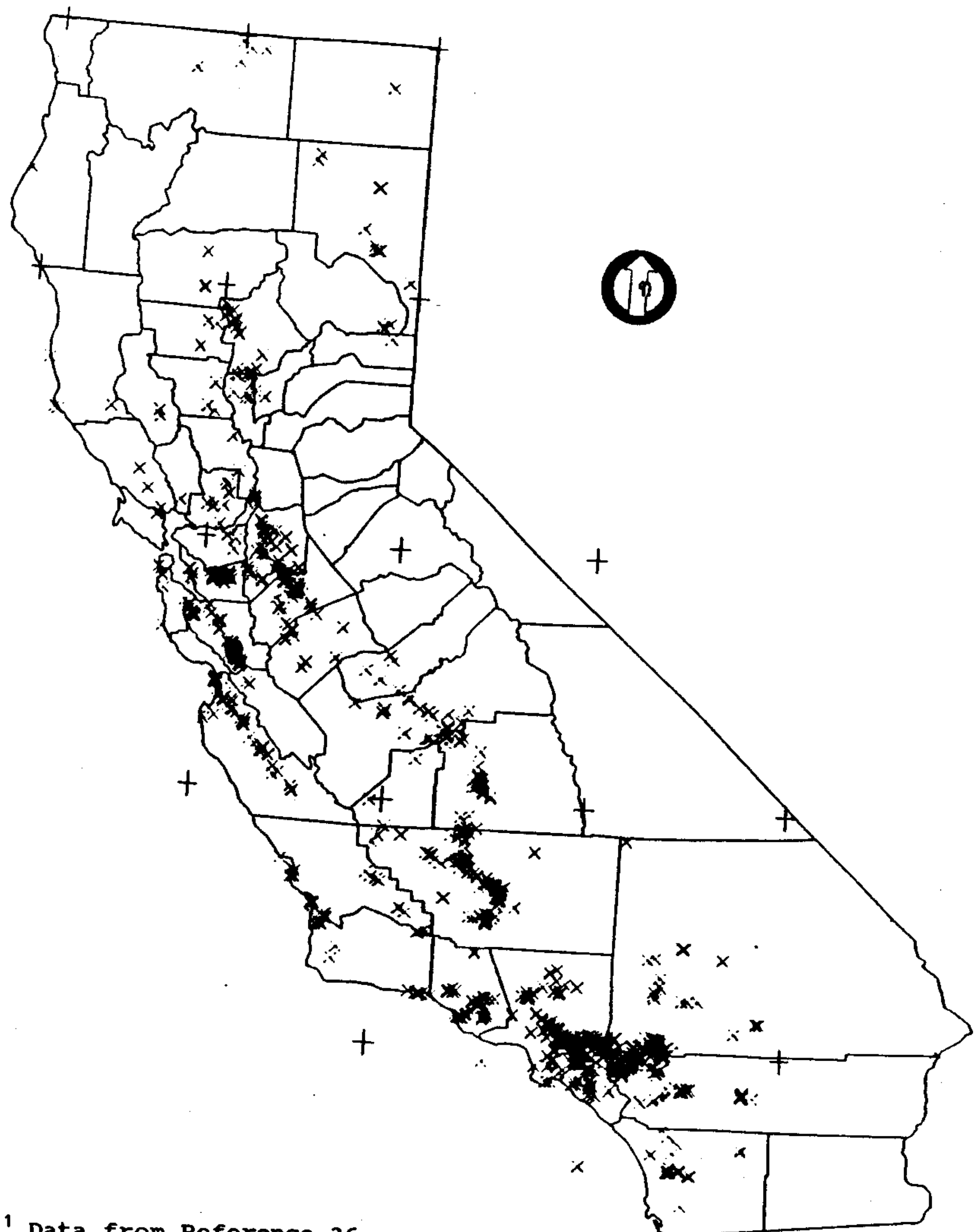
Board staff's extensive review of pertinent technical data and literature (see references at the end of this report) confirms that the increasing number of high density developments on septic systems in the Santa Ana Region will cause nitrate problems in areas otherwise unaffected by nitrate inputs. In areas with existing nitrate problems (irrespective of their source), high density septic system use will cause further degradation. As described in the next section of this report, large part of the ground water resource of the Santa Ana Region is already significantly impacted by nitrates.

2.3 High Nitrate in the Ground Water Subbasins of the Santa Ana Region

In 1988, the State Water Resources Control Board (State Board) prepared a report to the California Legislature on nitrate in the drinking waters of the State (Report No. 88-11 WQ) (36). The report includes a description of known nitrate contamination problems and a discussion of their sources. The report identifies the southern California coastal area, which, of course, includes the Santa Ana Region, as having the most severe nitrate problems within the State. This is evident from Figure 1, which is taken from the State Board report.

FIGURE 1[1,2]

Well Locations Where Nitrate Levels Have Been Recorded at 45 mg/l (as Nitrate) or Greater During the Period of 1975 through 1987



[1] Data from Reference 36
[2] Each symbol may represent more than one analysis at the same well

Regional Board staff conducted a detailed review of nitrate data available for the ground waters of the Santa Ana Region. Table 2 summarizes water quality data for selected drinking water supply wells with moderate to high levels of nitrate. (Note that the concentrations are expressed in mg/l of nitrate as nitrate; again, the drinking water standard is 45 mg/l nitrate as nitrate). Some of these data are depicted on Figure 2. It is clear from these data that there are serious, existing nitrate quality problems in the ground waters of the Region, and that these problems are not confined to small or localized areas but, rather, are virtually regionwide.

In 1987, the Metropolitan Water District of Southern California (MWD) compiled data on ground water quality within the MWD service area (which includes most of the Santa Ana Region) to evaluate the impacts of contamination by various parameters, including nitrate, on water supply (22). The data provided in this report, together with pertinent information from MWD's Chino Basin Ground Water Storage Program study (38) and input provided by Regional Board staff and other interested agencies and parties, is summarized in the State Board's report to the Legislature (36). The following summary was, in part, derived from this report and provides a good perspective of nitrate problems in the Santa Ana Region:

2.3.1 Orange County Area Ground Water Subbasins

Nitrate concentrations exceeding the State Action Level of 45 mg/l (as nitrate) affect about 250,000 acre-feet of ground water underlying Westminster, Garden Grove, Tustin, Fullerton, Anaheim, and Irvine. Nineteen eighty-seven (1987) data shows that an estimated 51 municipal wells have been taken out of service because of high nitrate and about 13 other wells produce water which must be blended for use as municipal supplies. [Note: Some of these data are included in Table 1].

The Orange County Water District is spending several million dollars for remediation of the nitrate contamination in these aquifers.

TABLE 2

SELECTED NITRATE DATA FOR WELLS IN VARIOUS GROUND WATER SUBBASINS IN THE SANTA ANA REGION

Ground Water Basin	Well Number	Nitrate as NO_3 (mg/l)	Date of Sampling
Riverside (1)	3S/5W-05Q	93	11/88 to
	3S/5W-14E	53	2/89
Temescal (1)	3S/6W-28M	80	"
	3S/6W-28L03	80	"
Arlington (1)	3S/6W-24Q	102	"
	3S/5W-6Q	97	"
Bunker Hill (1)	1S/3W-18L	49	"
Chino (1)	2S/7W-27R	429	"
	2S/7W-17H	248	"
	2S/7W-10M	199	"
Colton (1)	1S/5W-34J01	88	"
	1S/5W-25L	53	"
Santa Ana	5S/11W-1H01	91	Jul. 1977
Pressure (2)	3S/10W-10N03	69	Jul. 1976
Irvine Pressure	6S/9W-1A01	71	Nov. 1988
(2)	6S/9W-4L02	70	Apr. 1980
Santa Ana Forebay	3S/9W-21M05	137	Sep. 1980
(2)	3S/10W-10N03	100	Oct. 1966
Irvine Forebay II	5S/9W-16C01	80	Jan. 1988
(2)	5S/9W-16B02	64	1979

(1) Selected Data from Table 1 of Reference 26
(2) Data Provided by the Orange County Water District

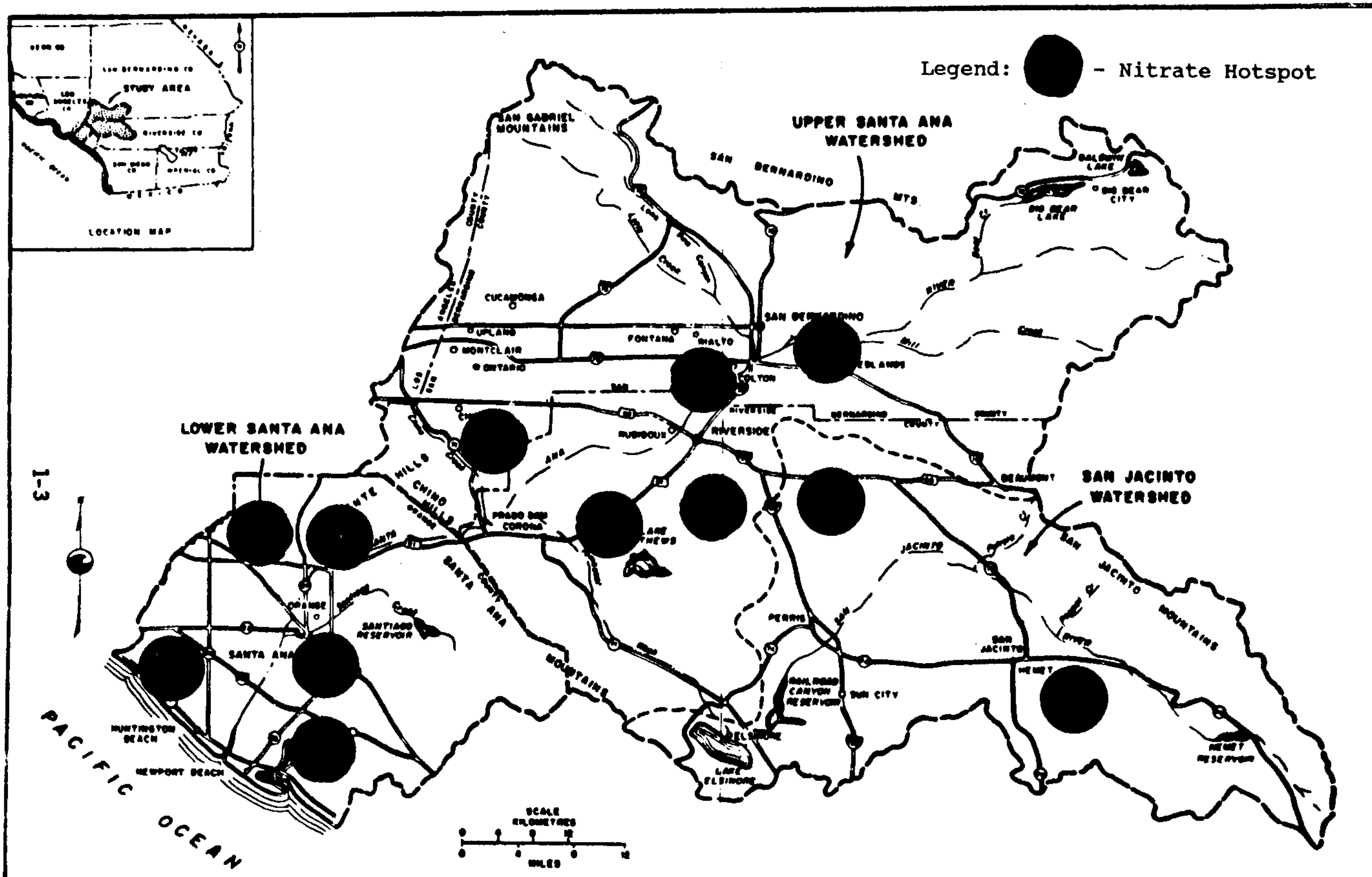


FIGURE 2 Nitrate "Hotspots" in Santa Ana Region

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1985

2.3.2 The Upper Santa Ana Ground Water Subbasins

The Upper Santa Ana River watershed is located in the southwest corner of San Bernardino County, in western Riverside County, and the very eastern part of Los Angeles County. It includes the prominent Chino, Riverside-Arlington, Temescal, Elsinore, and Bunker Hill Ground Water Basins, which have historically been heavily utilized for agriculture and municipal purposes.

(a) The Bunker Hill Basin in San Bernardino County has nitrates in ground water exceeding the State MCL in the areas of San Bernardino, Redlands, Highlands, East Highlands, Loma Linda, and adjacent to the Santa Ana River. The City of Riverside, which relocated its wells to this area because of nitrate in the Riverside Basin, has again had some impact from nitrate which required replacement wells.

(b) The Riverside-Arlington and the lower Temescal ground water basins are characterized by poor quality ground water. Nitrate exceeds 45 mg/l throughout the basins and the City of Riverside has closed most of its production wells for municipal uses and now derives 80 percent of its water from the Bunker Hill Basin. The City of Corona is about 50% dependent on ground water from the Temescal Basin and must buy imported water to blend with its supply to achieve an acceptable quality. The upper Temescal and Elsinore Basins still have very good quality water, with the exception of one small area found to have exceeded the State nitrate standards.

Within the Riverside, Temescal, Arlington, and Elsinore basins 64 of the 141 municipal wells exceed the State MCL for nitrate and total dissolved solids in drinking water. Of the 64 wells, 39 have been closed, 11 are used with blended water, nine are for nonpotable uses, four are operated above drinking water standards, and one is on standby. It is estimated that the water districts will have to buy an additional 12,000 acre-feet/year of imported water from Metropolitan Water District of Southern California (MWD). Five large water systems have requested financial aid under the Safe Drinking Water Bond Law of 1986 because of nitrate problems.

(c) The Chino Basin is an adjudicated basin in the western part of San Bernardino County and the northwestern part of Riverside County. Currently, ground water supplies 100 percent of the agricultural need and almost 90 percent of the municipal and industrial uses for the cities of Upland, Montclair, Ontario, Chino, Norco, and Fontana. Nitrate levels exceeding drinking water standards occur in 89 of 860 wells in the basin. Municipal wells have been replaced elsewhere in the basin or blending has been required to produce acceptable water.

2.3.3 San Jacinto Ground Water Subbasins

The relatively limited data for this area indicate ground water contamination by nitrates in excess of the drinking water standard in the Hemet and Moreno Valley areas. Additional data and projections of future ground quality will be provided through the ongoing SAWPA/SARDA nitrogen study.

2.4 Sources of Nitrate Inputs

There are a number of sources of the nitrate contamination found in the waters of the Region. The State Board report on nitrate in drinking water identified septic system use and agricultural activities (including dairies and feedlots) as the two predominant sources in California. Other sources include effluent from municipal sewage treatment plants and urban runoff.

2.5 Need for Control of Septic Systems

Clearly, the foregoing summary of nitrate problems indicates that the majority of the ground water subbasins in the Region already lack assimilative capacity for nitrogen inputs of whatever type: the drinking water standard for nitrate has been exceeded and numerous domestic supply wells have been removed from normal service. Irrespective of the source(s) of the nitrate contamination now present, it is clear that additional high mass loading of nitrates from high density septic system use can only result in further degradation (more detailed calculations and explanation of this phenomenon are presented below). As stated previously, even in those subbasins not currently impacted by nitrates, high density septic system use will ultimately lead to water quality degradation.

The ground water subbasins of the Santa Ana Region are among the most significant in southern California. Ground water constitutes approximately 60% of the total water supplies for the Region. Critical evaluation of any existing or potential threat to this source of supply is imperative. To address existing nitrate problems in the ground (and surface) waters of the Region, and to prevent nitrate problems in the future, it is necessary to take appropriate steps to control each of the various types of nitrogen inputs. Extensive efforts are now underway (SAWPA/SARDA Nitrogen study and other Basin Plan update activities) to develop management plans for nitrogen from sewage treatment plants, dairies and other sources. These plans will likely entail significant expenditures and operational changes. In view of these efforts, we would be remiss if we did not consider septic system control options. The public workshop held on April 14, 1989 was the first step toward this objective.

On April 14, 1989, the Regional Board conducted a public workshop to discuss the interrelationship between high density use of subsurface wastewater disposal systems and nitrate contamination problems in the ground waters of the Fontana/Bloomington area of San Bernardino County.* The Board's focus on that area was due to the particularly extensive development of high density lots on septic systems. At that workshop, staff described a number of alternate methods which could be used to address this problem and recommended that additional evaluation be conducted to identify the most effective and feasible approach (37). At the conclusion of the workshop, the Board directed staff to continue the studies and to develop a recommendation to address this problem.

Based on the review of the regionwide ground water quality data previously presented, and the finding that most of the subbasins of the Region show nitrate impairment, staff believes that the control of septic system use must be addressed on a regionwide, not merely localized basis. The following sections of this report identify and describe control options which might be employed.

* See Appendix

3.0 SEPTIC TANK-SUBSURFACE DISPOSAL SYSTEMS-AN OVERVIEW

3.1 Septic Tanks

A septic tank is a buried, watertight receptacle designed and constructed to receive sanitary wastewater, to separate solids from the liquid, to provide limited digestion of organic matter, to store solids, and to allow the clarified liquid to discharge for further treatment and disposal. A scum of lightweight material (including fats and greases) rises to the top. The partially clarified liquid is allowed to flow through an outlet structure just below the floating scum layer. Clarified liquid can be disposed of to soil absorption systems.

3.2 Soil Absorption Systems (Subsurface Disposal Systems)

Basically, there are two different types of subsurface disposal systems:

(a) Subsurface soil absorption systems which include trenches and beds (see Figure 3), seepage pits (see Figure 4), mounds, fills, artificially drained systems, and electro-osmosis systems

(b) Evapotranspiration systems

The two most common onsite subsurface disposal systems used within this Region are leach trenches (see Figure 3) and seepage pits (Figure 4).

Under suitable conditions (soil type, temperature, moisture and oxygen content), soils have a high capacity to accept, assimilate, and treat sewage effluent. Many soils are effective media which filter the organic matter and remove bacteria from septic tank effluent.

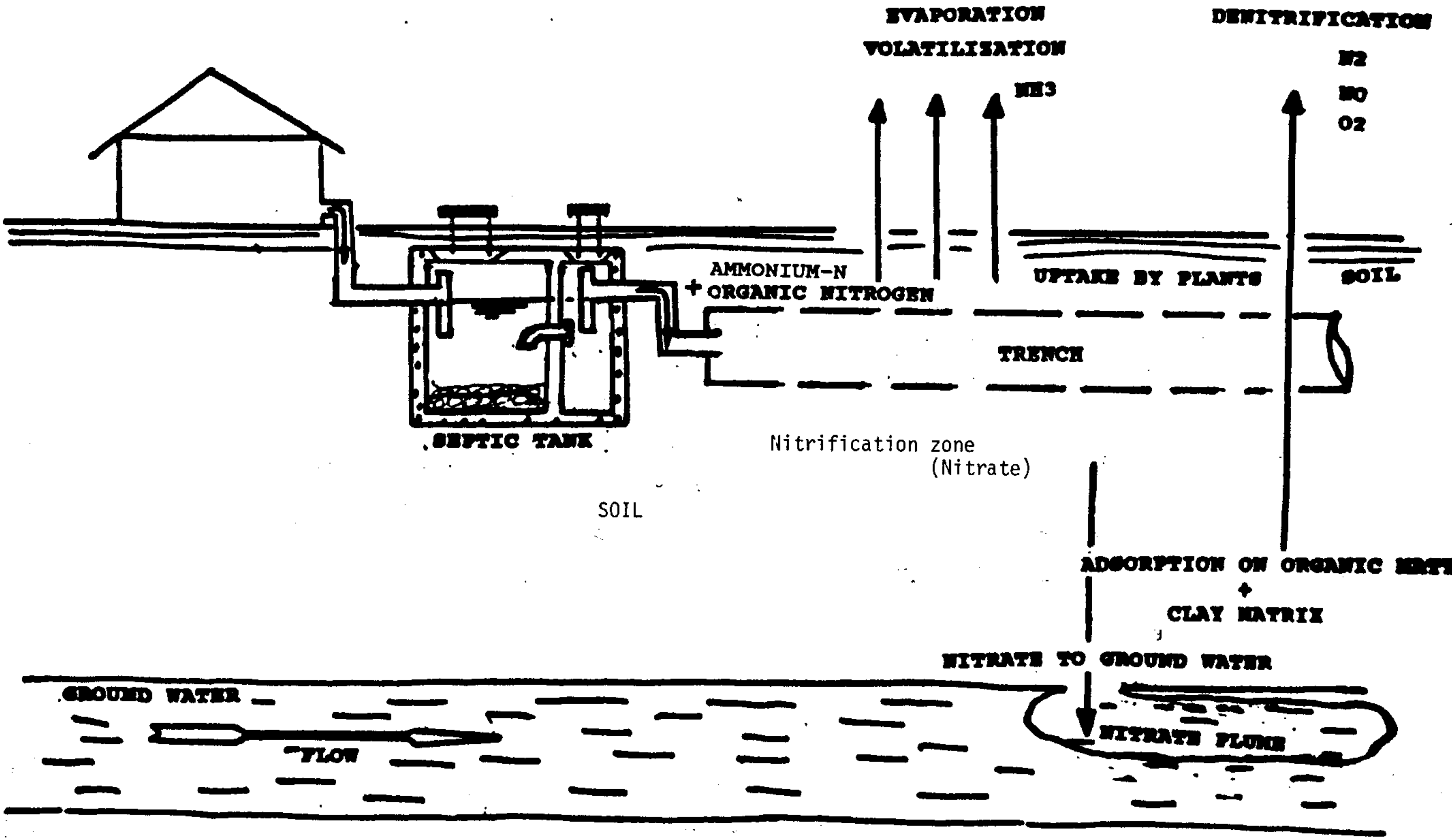
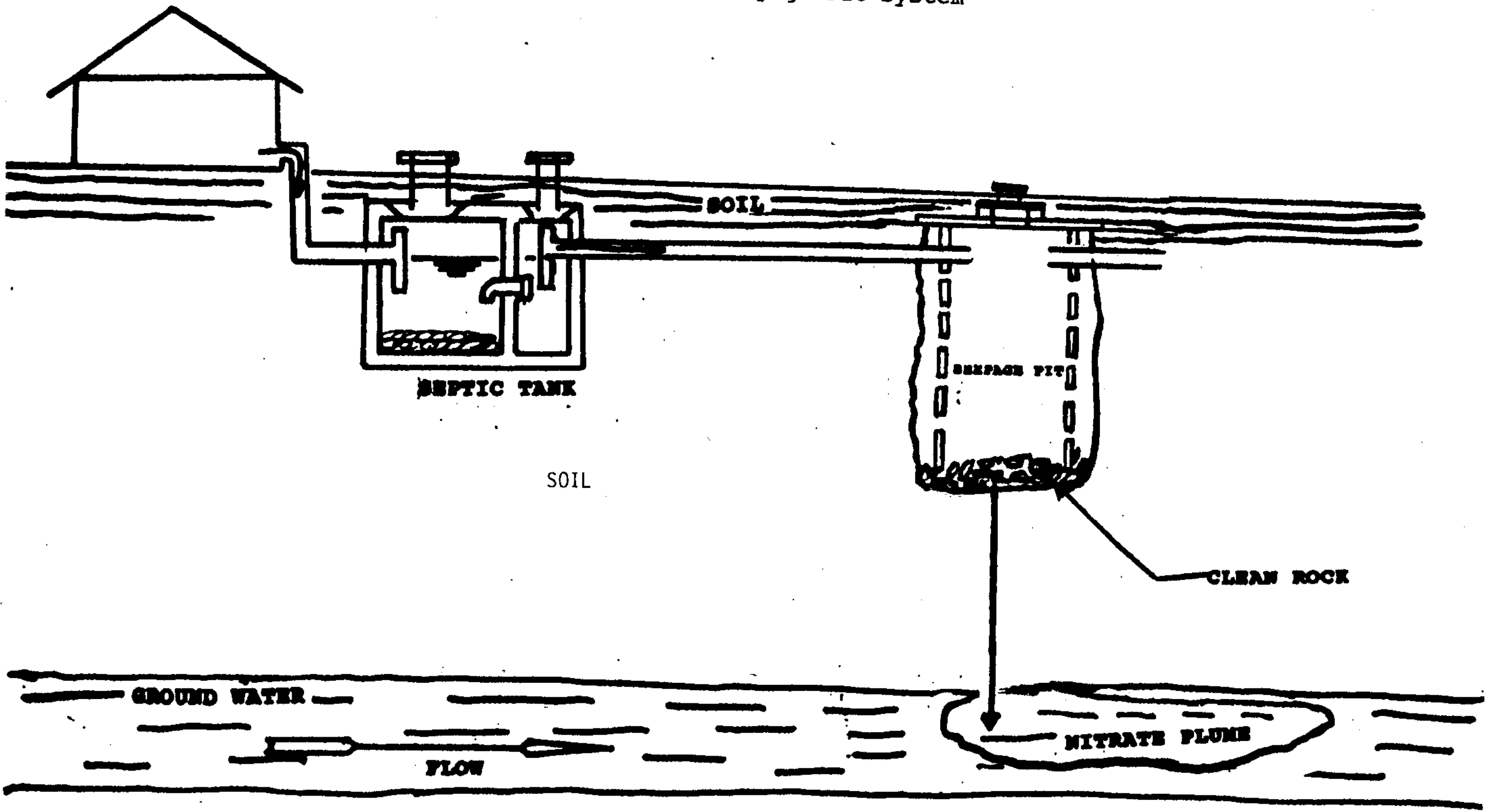


FIGURE 3 SEPTIC TANK - TRENCH SYSTEMS AND NITROGEN TRANSFORMATIONS

FIGURE 4

Septic Tank-Seepage Pit System



Proper design and operation of on-site septic systems can effectively eliminate the threat of bacterial contamination and disease transmission. Standard siting and design criteria for on-site sewage disposal systems are designed mainly toward this end, i.e., to protect water quality and public health from the standpoint of bacterial contamination and disease transmission. It is important to understand that these design criteria do <u>not</u> address water quality problems related to the loading of nitrate and other nutrients and total dissolved solids (TDS) to ground water by septic tank effluents. Nor do these standard criteria consider the cumulative impacts of multiple systems. Ground water quality degradation with respect to nitrate (and other parameters like TDS) can be expected when septic systems are used in high density developments, particularly where the developments cover a large portion of the natural ground water recharge area (less natural recharge is then available to dilute the septic tank effluent).

From a water quantity standpoint, septic tank effluent recharges the aquifer. However, from a water quality perspective, recharge with poor quality effluent is not beneficial. As discussed earlier, nitrate loading from septic systems poses a significant threat to domestic water supplies.

In order to understand the nitrate threat to water quality posed by septic systems, let us first examine the nitrogen constituents of septic tank effluent and their transformations and movement in the soil.

4.0 WASTEWATER CHARACTERISTICS OF SEPTIC TANK EFFLUENT

The effluent from the septic tank is discharged to the soil through the subsurface disposal system (generally, a leach trench or a seepage pit). This effluent contains a number of constituents which could adversely impact water quality. These constituents include pathogens (bacteria and viruses), biodegradable organics, refractory organics (from household products such as disinfectants, cleaning materials, cosmetics, paint, pesticides, etc.), heavy metals, nutrients (both phosphorus and nitrogen), and other dissolved inorganics. The characteristics of typical residential wastewater (35) are shown in Table 3 (35). Of these, nitrogen in the form of nitrate is generally the first contaminant associated with septic system effluent to exceed public health standards and is, therefore, a potential threat to public health and ground water resources. (Note that the actual nitrate concentration in septic tank effluent is low, less than 1 mg/l. However, the nitrogen components of the effluent, particularly ammonia, are transformed to nitrate in the underlying soil. This nitrate passes to ground water (see section 4.2)).

4.1 Nitrogen Compounds in Septic Tank Effluent

As shown in Table 3, the total nitrogen content of residential wastewater (mass loading) varies from 6 to 17 grams per capita per day (gm/c/d), which corresponds to a concentration of 13.3 to 150.8 mg/l. These variations are due to several factors such as socioeconomic status, geographic location, water supply quality, number and age of family members, plumbing fixtures, and appliances present and frequency of their use. Table 4 is an excerpt from Reference 4 and shows the wide variations in the reported values of total nitrogen concentrations.

Nitrogen is present in various forms in sanitary wastewater. The major components are ammonium-nitrogen (55-80 percent) and organic nitrogen. The reported concentrations for these components also vary over a wide range. Table 5 shows the relative concentrations of the various forms of nitrogen present in septic tank effluent (39).

Table 6 is a comparison of the total nitrogen concentrations in rain water, sewage treatment plant effluent, and septic tank effluent. This comparison indicates a significant nitrogen contribution from septic tank effluent compared to other sources.

TABLE 3[2]

CHARACTERISTICS OF TYPICAL RESIDENTIAL WASTEWATER

PARAMETER	MASS LOADING gm/c/d	CONCENTRATION mg/l
Total Solids	115-170	680-1000
Volatile Solids	65-85	380-500
Suspended Solids	35-50	200-290
Volatile Suspende Solids	25-40	150-240
BOD_5	35-50	200-290
Chemical Oxygen Demand	115-125	680-730
Total Nitrogen	6-17	35-100
Ammonia	1-3	6-18
Nitrites and Nitrates	<1	<1
Total Phosphorus	3-5	18-29
Phosphate	1-4	6-24
Total Coliforms[1]	-	10^{10}-10^{12}
Fecal Coliforms[1]	-	10^{8}-10^{10}

1. Concentrations in organisms per liter

2. Data from Reference 35

TABLE 4[1]

Averaged Concentrations (mg/l) of Nutrient Constituents Present in Septic Tank Effluent

Nutrient (mg/l)	Schroepfer (1964)	Pruel (1964)	Watson (1966)	Corey (1967)	Boyle (1970)	New York Health Dept. (1969)	Polta (1969)
Ammonia-N	60	25	64	33.6	14	86.3	25
Organic-N	--	10	--	10.3	16.2	--	10
Nitrite & Nitrate-N	.01	.15	--	.24	.09	.09	0
Total-N	--	35	84	44	30	--	35
Total-P	20	20	61	7.4	5.4	70	--
Ortho-P	--	--	37	--	--	--	20
Number of systems studied	6	6	3	2	1	2	1

[1] Data from Reference 4

TABLE 5[1]

Median Concentrations from Six Septic Tank Effluents (mg/l)

System	Total-N	Ammonia-N	Organic-N	Nitrate & Nitrite-N
1	45	38	7	0.4
2	70	37	24	1.0
3	43	35	4	0.5
4	40	32	5	0.2
5	50	38	5	0.3
6(two tanks in series)	36	21	9	0.2
Mean	47	34	9	0.4

[1] Data from Reference 4

TABLE 6

A COMPARISON OF TOTAL NITROGEN CONCENTRATIONS IN VARIOUS SOURCES

WATER/WASTEWATER TYPE	TOTAL NITROGEN CONCENTRATION
1. Precipitation	0-1.0 mg/l
2. Sewage Treatment Plant Effluent[1]	15-25 mg/l
3. Septic Tank Effluent	35-100 mg/l

[1]. From Monitoring Reports submitted by STPs (secondary/tertiary treated effluent)

The various forms of nitrogen, introduced into the soil through the subsurface disposal system, undergo transformations as they migrate through the soil.

4.2 Nitrogen Transformations

The mobility of ammonium and organic forms of nitrogen in soil depends upon the oxidation-reduction potential of the soil. Generally, the ammonium and organic forms of nitrogen present in the septic tank effluent are not very mobile. Most of the organic nitrogen is converted to ammonium-nitrogen (NH_4^+-N) by the bacterial enzymes in the soil (mineralization).

$$\text{Organic-N} \xrightarrow{\text{bacterial enzymes}} NH_4^+ + \text{other products}$$

(mineralization)

Mineralization can be carried out under aerobic or anaerobic conditions.

Ammonium-N so produced is converted first to nitrite and then to nitrate by the soil bacteria (nitrification).

$$NH_4^+ + 1.5\ O_2 \xrightarrow{\text{Nitrosomonas}} \underset{\text{(nitrite)}}{NO_2^-} + 2H^+ + H_2O + \text{energy}$$

$$NO_2^- + 0.5\ O_2 \xrightarrow{\text{Nitrobacter}} \underset{\text{(nitrate)}}{NO_3^-} + \text{energy}$$

(nitrification)

Nitrification can occur in the soil in aerobic zones only. Unlike ammonium and organic forms of nitrogen, nitrate is a soluble ion and can readily move with water. Under suitable conditions, most of the nitrogen in the septic tank effluent is converted to nitrate ions and is carried to the ground water by the wastewater discharges/deep percolating precipitation.

Some of the nitrate is immobilized by plants or through microbial uptake. However, since most nitrification occurs below the root zone, nitrate loss from plant uptake is insignificant, especially in septic tank-seepage pit systems.

Under anaerobic conditions, nitrate can be converted to nitrogen gas in the unsaturated zone (denitrification).

$$NO_3^- + \text{Organic carbon source} \xrightarrow{\text{denitrifying bacteria}} N_2 + H_2O + CO_2$$

(denitrification)

Because these denitrifying bacteria also require a source of carbon for energy, denitrification occurs primarily where organic material is abundant, such as directly beneath the trench beds. Deep, sandy, well-drained soils with low organic matter content have negligible denitrification potential; sandy loam soils have medium denitrification potential (10 to 20% N loss); and finer textured soils such as silts and clays have high potential for denitrification (20 to 40% N loss) (40,41). For example, in the Fontana/Bloomington area where seepage pits are used on high density developments (generally there is more denitrification in trench beds than with seepage pits), nitrogen loss due to denitrification should be negligible. 0 to 25% denitrification rates are considered as the average for most areas (3).

In summary, a small percentage of the nitrogen from the raw sewage is removed by the septic tank, through evapotranspiration, and through denitrification. Most of the nitrogen in the septic tank effluent is converted to nitrate and migrates through the soil to the underlying ground water.

5.0 NITRATES FROM SEPTIC SYSTEMS-MIGRATION TO GROUND WATER

Using a set of mathematical equations which form a simple modelling tool, we can calculate the impact of the nitrate produced from septic tank effluent on underlying ground water. We can also determine the minimum lot size required to prevent adverse ground water quality effects from septic system use. Several steps are involved:

1. Calculate the concentration of nitrate in the water that is percolating through the soil.

2. Examine how this concentration changes with the lot size.

3. Calculate a lot size that will limit the concentration of nitrate in the percolate to the drinking water standard (10 mg/l nitrate as nitrogen).

5.1 Calculate the nitrate concentration of water percolating through the soil to ground water

A number of factors must be considered in calculating the nitrate concentration of the percolate (e.g. denitrification rates, wastewater flow, precipitation rate, lot size, etc.). The following series of computations take each of these factors into account sequentially.

Before proceeding, it is important to note that there is a range of values for each of the factors considered. The calculated nitrate concentration therefore varies according to the values assumed. The calculations presented in the text reflect values which are documented in the literature (see references by the assumed numbers and at the end) or at least appear reasonable for the conditions in the Region. As will be explained below, the results of computations using the various ranges of values are also presented graphically.

5.1.1 Total Nitrogen Loading Rate of Septic Tank Effluent

As shown in Table 7, the flow rates reported for wastewater flows from residential use vary widely. The total nitrogen concentrations in the septic tank effluent also vary with the flow rates. The range of mass loading rates and flow rates reported in the EPA Design Manual (35) is used to calculate the nitrate concentrations. The actual nitrate concentration of the wastewater effluent from a septic tank would be within the range of values so obtained.

A typical calculation using the lowest reported mass loading rate of 6 gm/capita/d is shown below:
Total nitrogen loading rate of raw sewage = 6 gm/capita/day (12, 35)

(gm/c/d)

The septic tank removes approximately 15% of this nitrogen (42):

Total nitrogen loading rate of septic tank effluent
= 6 x 0.85
= 5.1 gm/c/d

TABLE 7[1]

Summary of Average Daily Residential Wastewater Flows

Study	No. of Residences	Duration of Study, months	Wastewater Flow Study Average, gpcd	Range of Individual Residence Average, gpcd
Linaweaver, et al.	22	-	49	36-66
Anderson and Watson	18	4	44	18-69
Watson, et al.	3	2-12	53	25-65
Cohen and Wallman	8	6	52	37.8-101.6
Laak	5	24	41.4	26.3-65.4
Bennett and Linstedt	5	0.5	44.5	31.8-82.5
Siegrist, et al.	11	1	42.6	25.4-56.9
Otis	21	12	36	8-71
Duffy, et al.	16	12	42.3	-
		Weighted Average	44.0	

[1] Data from Reference 35

5.1.2 Denitrification Losses (0-25%)

As described above, almost all the nitrogen is converted (nitrified) to nitrate in the unsaturated zone in well-aerated soil. Most of this nitrate will be carried by the wastewater and the recharge water to the ground water. However, depending upon the conditions, some denitrification of the nitrified effluent is to be expected as discussed above. As stated above, denitrification rates between 0 and 25% are considered as the average. For denitrification rates between 0 and 25%, the resulting total nitrogen loading rates would be as follows:

Total Nitrogen Content After Denitrification:

0% denitrification	=	5.1 gm/c/d
15% denitrification	=	5.1 (1-.15)
	=	4.34 gm/c/d
25% denitrification	=	5.1 (1-.25)
	=	3.83 gm/c/d

This is the total amount of nitrogen (mostly in the nitrate form) migrating to the ground water.

5.1.3 Wastewater Flow Rates/Nitrogen Concentration

The average daily flow at one residence compared to that of another can vary considerably; it is typically no greater than 60 gal/capita/day (gpcd) (35). A summary of average daily wastewater flows according to various studies is shown in Table 7. Let us start with the design flow rate of 60 gpcd per the EPA design manual (35).

Wastewater flow = 60 gal/c/d
= 230 liters/c/d (l/c/d)

$$\text{Total nitrogen concentration } (N_{ww}) = \frac{5.1 \text{ gm/c/d}}{230 \text{ l/c/d}}$$
$$= 0.02217 \text{ gm/l}$$
$$= 22.17 \text{ mg/l}$$

(This is for a flow rate of 60 gpcd and 0% denitrification.)

If the other denitrification rates (15%, 25%) are considered as well, total nitrogen concentration in the wastewater percolating into the ground water would be from 16.63 mg/l to 22.17 mg/l.

Now, let us consider other wastewater flow rates.

(For 0% denitrification)

For 25 gpcd, the total nitrogen concentration = 53.2 mg/l
For 50 gpcd, the total nitrogen concentration = 26.61 mg/l
For 75 gpcd, the total nitrogen concentration = 17.74 mg/l

Table 8 is a summary of total nitrogen concentrations for various flow rates and denitrification rates. Thus, the nitrate-N concentration of septic tank effluents could range from 13.30 mg/l to 150.79 mg/l. The value generally reported in the literature for nitrate-N in septic system effluent is 35 to 100 mg/l. Again, most of this nitrogen has undergone nitrification and is in the nitrate form.

In the absence of any recharge water to dilute this wastewater, the underlying ground waters would receive this nitrate concentration.

5.2 Dilution by Recharge Waters/Nitrate Concentration in the Total Percolate

Recognizing that some dilution of septic tank effluent by recharge waters is likely to occur, it is appropriate to calculate the nitrate loading from the total percolate. Total percolate is the sum of the volumes of wastewater (septic tank effluent) flow and recharge waters. The nitrate concentration of the total percolate is calculated using Equation 1 (43).

$$N_{tp} = \frac{(N_{ww})\ (WW_L)\ +\ (N_{DP})\ (DP)}{(WW_L+DP)} \qquad (1)$$

where:

N_{tp} = nitrate-N in the total percolate (mg/l)
N_{ww} = " " " " " wastewater (mg/l)
WW_L = Wastewater loading (in/yr)
N_{DP} = Nitrate - N in the deep percolate (mg/l)
DP = Deep percolate (in/yr)

Now let us look at each of the above factors:

TABLE 8

VARIATIONS IN CRITICAL DENSITY (D_c) WITH NITRATE-N IN WASTEWATER (N_{ww}), NITROGEN MASS LOADINGS, DENITRIFICATION RATES, AND WASTEWATER FLOW RATES

Mass Loading (gm/c/d)	Denitrification (%)	Wastewater Flow (gal/c/d)	N_{ww} (mg/l)	D_c (acres/unit)
6	0	25	53.20	2.97
		44	30.24	1.39
		50	26.61	1.14
		75	17.74	0.53
	15	25	45.24	2.42
		44	25.70	1.08
		50	22.62	0.87
		75	15.08	0.35
	25	25	39.91	2.05
		44	22.68	0.87
		50	19.96	0.68
		75	13.30	0.23
12	0	25	106.44	6.63
		44	60.47	3.47
		50	53.22	2.97
		75	35.50	1.75
	15	25	90.47	5.53
		44	51.40	2.84
		50	45.24	2.42
		75	28.30	1.26
	25	25	79.83	4.80
		44	45.35	2.43
		50	39.92	2.06
		75	26.60	1.14
17	0	25	150.79	9.67
		44	85.67	5.20
		50	75.39	4.49
		75	50.26	2.77
	15	25	128.17	8.12
		44	72.82	4.32
		50	64.08	3.72
		75	42.72	2.25
	25	25	113.09	7.08
		44	64.25	3.73
		50	56.54	3.20
		75	37.70	1.90

5.2.1 Nitrate-N in the Wastewater (N_{ww})

As seen in the preceding section, the concentration of nitrate nitrogen in the wastewater percolate (N_{ww}) is dependent on denitrification losses and wastewater flow rates (Table 8). For the purpose of solving Equation 1, a value of 17.74 mg/l is assumed (this assumes a rather liberal 75 gpcd wastewater flow rate and 0% denitrification). Denitrification is relatively insignificant in deep sandy soils found in many areas of the Region.

5.2.2 Calculation of Wastewater Loading Rate (WW_L)

The wastewater loading rate (WW_L) is dependent on both the wastewater flow and the lot size. Wastewater flow from a single family residence ranges from 150 gal/day to 360 gal/day (35) (Note that this is not the flow rate per capita; this is per dwelling unit). If we assume a 7,000 square feet lot (typical of high density developments in the Region), then for 150 gal/day we have the following wastewater loading rate:

$$
\begin{aligned}
WW_L &= 150 \text{ gal/day} \\
&= 54750 \text{ gal/yr} \\
&= 7319.5 \text{ ft}^3\text{/yr} \\
&= 7319.5/7000 = 1.04 \text{ ft/yr} \quad \text{(for a 7000 square feet lot)} \\
&= 12.5 \text{ in/yr}
\end{aligned}
$$

For a 20,000 square feet lot:

$$
\begin{aligned}
WW_L &= 7319.5/20000 = 0.4 \text{ ft/yr} \\
&= 4.4 \text{ in/yr}
\end{aligned}
$$

Table 9 shows calculated wastewater loading rates and nitrate-N in the total percolate using a range of assumptions for both flow and lot size.

It can be seen from Table 9 that the wastewater loading factor is significantly affected by the lot size. Therefore, the density of septic systems in an area is an important parameter affecting the total nitrate concentration which reaches ground water.

TABLE 9

Relationship Between Lot Size, Wastewater Flow, Wastewater Loading Rates, and Nitrate Concentration in Total Percolate (N_{tp}) for 15% Denitrification Rate

Lot Size (ft^2)	Flow (gpd)	Wastewater Loading (in/yr)	Ntp (mg/l)
7,000	150	12.5	22.67
	200	16.73	23.86
	300	25.10	25.17
	360	30.11	25.64
10,890 (1/4 ac)	150	8.04	20.44
	200	10.75	21.96
	300	16.13	23.72
	360	19.36	24.38
21,780 (1/2 ac)	150	4.08	16.20
	200	5.38	18.02
	300	8.06	20.45
	360	9.68	21.44

5.2.3 Calculation of Deep Percolate (DP)

Recharge waters (other than septic tank effluent) include the following:

a. Deep percolation of precipitation-Table 10
b. Percolation of used water (irrigation)-Table 11
c. Streambed percolation-Table 12
d. Diverted artificial recharge-Table 13
e. Imported recharge-Table 14

Deep percolation is affected by the amount of precipitation losses due to evaporation and evapotranspiration and runoff from impervious areas. In a high density development, the construction of roads, drive-ways, patios, sidewalks, etc., substantially reduces the area available for rainfall percolation, and the runoff from the area increases. The deep percolate is available for diluting the wastewater discharges from the septic systems. Tables 10 through 14 show the projections by subbasin for the deep percolate as used in the Basin Planning Procedure (1983 Basin Plan). Table 15 shows some historical relationship between precipitation and deep percolation. It is evident from Tables 10 through 14 that the majority of the deep percolate is from precipitation. For many of the ground water subbasins in this Region, the only deep percolate is from precipitation. Therefore, it is appropriate to use the average values from Table 15 for deep percolate (DP = 3.25 in.).

5.2.4 Nitrate in the Deep Percolate (N_{DP})

Generally, rain water contains 0 to 1 mg/l of nitrate-nitrogen. In addition, there are other sources of nitrogen in the deep percolate (excess nitrogen from fertilizer used on the lawns, nitrogen in recharge waters other than rain water, such as State Water Project water). It is difficult to estimate the nitrogen contributions in the recharge waters from these sources. We will use 1 mg/l (as N) as the nitrate concentration in the deep percolate, as the following calculations assume the deep percolate to be all rain water.

TABLE 10[1]

PROJECTIONS BY SUBBASIN OF THE VOLUME OF PERCOLATION OF PRECIPITATION WHICH REACHES THE GROUND WATER RESERVOIR UNDER THE UPPER SANTA ANA RIVER WATERSHED

YEAR	SB # 1	Q&C	SB # 2	Q&C	SB # 3	Q&C	SB # 4	Q&C	SB # 5	Q&C	SB # 6	Q&C	SB # 7	Q&C	SB # 8	Q&C
1980	25089.	180.	7117.	180.	7397.	180.	8881.	180.	24890.	180.	12571.	180.	24576.	180.	6802.	180.
1985	24470.	180.	6852.	180.	7122.	180.	8758.	180.	24254.	180.	12408.	180.	23969.	180.	6681.	180.
1990	23832.	180.	6592.	180.	6838.	180.	8639.	180.	23645.	180.	12251.	180.	23360.	180.	6555.	180.
1995	23182.	180.	6332.	180.	6563.	180.	8510.	180.	23020.	180.	12092.	180.	22752.	180.	6431.	180.
2000	22551.	180.	6068.	180.	6285.	180.	8389.	180.	22387.	180.	11939.	180.	22161.	180.	6304.	180.

YEAR	SB # 9	Q&C	SB #10	Q&C	SB #11	Q&C	SB #12	Q&C	SB #13	Q&C	SB #14	Q&C	SB #15	Q&C	SB #16	Q&C
1980	9333.	180.	2341.	180.	2437.	180.	11356.	180.	3982.	180.	523.	180.	4605.	180.	3216.	180.
1985	9322.	180.	2248.	180.	2326.	180.	11184.	180.	3957.	180.	519.	180.	4569.	180.	3174.	180.
1990	9319.	180.	2154.	180.	2213.	180.	11013.	180.	3918.	180.	515.	180.	4537.	180.	3131.	180.
1995	9310.	180.	2064.	180.	2107.	180.	10838.	180.	3884.	180.	512.	180.	4502.	180.	3086.	180.
2000	9318.	180.	1974.	180.	1996.	180.	10659.	180.	3845.	180.	509.	180.	4469.	180.	3047.	180.

SB #1 = CHINO ZONE-1
SB #2 = TEMESCAL
SB #3 = RIVERSIDE
SB #4 = RIALTO
SB #5 = BUNKER HILL ZONE-2
SB #6 = SAN TIMOTEO
SB #7 = CHINO ZONE-2
SB #8 = CHINO ZONE-3

SB #9 = BUNKER HILL ZONE-1
SB #10 = ARLINGTON
SB #11 = COLTON
SB #12 = CUCAMONGA
SB #13 = POMONA
SB #14 = UPPER TEMESCAL
SB #15 = CLAREMONT HEIGHTS
SB #16 = LYTLE CREEK BASIN

[1] Data from Reference 44

Legend: Q&C - Quantity (Acre-Feet) & Total Dissolved Solids Concentration (mg/l)

TABLE 11[1]

PROJECTIONS BY SUBBASIN OF THE VOLUME
RETURNING FROM USE WHICH ENTERS THE TOP OF THE
GROUND WATER RESERVOIR UNDER
THE UPPER SANTA ANA RIVER WATERSHED

YEAR	SB # 1 Q	SB # 2 Q	SB # 3 Q	SB # 4 Q	SB # 5 Q	SB # 6 Q	SB # 7 Q	SB # 8 Q
1980	15871.	11192.	7490.	5010.	48101.	8302.	37319.	70933.
1985	15927.	10597.	7410.	4731.	34965.	11899.	37140.	78956.
1990	15582.	10755.	6953.	4524.	33322.	11494.	34158.	94286.
1995	13358.	10245.	6416.	4088.	31756.	11102.	29750.	101078.
2000	13551.	10286.	6626.	4237.	31964.	11249.	29608.	106342.

YEAR	SB # 9 Q	SB #10 Q	SB #11 Q	SB #12 Q	SB #13 Q	SB #14 Q	SB #15 Q	SB #16 Q	SB #17 Q
1980	2094.	2269.	9116.	3139.	2291.	460.	2341.	837.	0.
1985	2060.	2308.	26016.	3182.	2310.	504.	2377.	871.	0.
1990	1945.	2178.	32047.	3600.	2063.	650.	2196.	746.	0.
1995	1829.	2008.	33113.	2813.	1766.	915.	1910.	691.	0.
2000	1899.	2065.	34644.	2883.	1738.	958.	1881.	715.	0.

SB #1 = CHINO ZONE-1
SB #2 = TEMESCAL
SB #3 = RIVERSIDE
SB #4 = RIALTO
SB #5 = BUNKER HILL ZONE-2
SB #6 = SAN TIMOTEO
SB #7 = CHINO ZONE-2
SB #8 = CHINO ZONE-3

SB #9 = BUNKER HILL ZONE-1
SB #10 = ARLINGTON
SB #11 = COLTON
SB #12 = CUCAMONGA
SB #13 = POMONA
SB #14 = UPPER TEMESCAL
SB #15 = CLAREMONT HEIGHTS
SB #16 = LYTLE CREEK BASIN
SB #17 = BUNKER HILL CONFINED

[1] Data from Reference 44

Legend: Q&C - Quantity (Acre-Feet) & Total Dissolved Solids Concentration (mg/l)

TABLE 12[1]

PROJECTIONS BY SUBBASIN OF THE COMBINED VOLUME OF STREAMBED PERCOLATION AND URBAN RUNOFF WHICH REACHES THE GROUND WATER RESERVOIR UNDER THE UPPER SANTA ANA RIVER WATERSHED

YEAR	SB # 1	Q&C	SB # 2	Q&C	SB # 3	Q&C	SB # 4	Q&C	SB # 5	Q&C	SB # 6	Q&C	SB # 7	Q&C	SB # 8	Q&C
1980	1659.	200.	0.	0.	6852.	200.	0.	0.	41996.	200.	4814.	200.	1615.	200.	0.	0.
1985	1698.	200.	0.	0.	6900.	200.	0.	0.	42078.	200.	4849.	200.	1654.	200.	0.	0.
1990	1741.	200.	0.	0.	6948.	200.	0.	0.	42177.	200.	4888.	200.	1694.	200.	0.	0.
1995	1783.	200.	0.	0.	6995.	200.	0.	0.	42263.	200.	4920.	200.	1736.	200.	0.	0.
2000	1825.	200.	0.	0.	7043.	200.	0.	0.	42352.	200.	4954.	200.	1776.	200.	0.	0.

YEAR	SB # 9	Q&C	SB #10	Q&C	SB #11	Q&C	SB #12	Q&C	SB #13	Q&C	SB #14	Q&C	SB #15	Q&C	SB #16	Q&C
1980	22541.	200.	0.	0.	13318.	200.	1619.	200.	0.	0.	0.	0.	0.	0.	16730.	200.
1985	22560.	200.	0.	0.	13410.	200.	1658.	200.	0.	0.	0.	0.	0.	0.	16743.	200.
1990	22578.	200.	0.	0.	13502.	200.	1700.	200.	0.	0.	0.	0.	0.	0.	16757.	200.
1995	22594.	200.	0.	0.	13594.	200.	1741.	200.	0.	0.	0.	0.	0.	0.	16770.	200.
2000	22613.	200.	0.	0.	13688.	200.	1782.	200.	0.	0.	0.	0.	0.	0.	16781.	200.

SB #1 = CHINO ZONE-1
SB #2 = TEMESCAL
SB #3 = RIVERSIDE
SB #4 = RIALTO
SB #5 = BUNKER HILL ZONE-2
SB #6 = SAN TIMOTEO
SB #7 = CHINO ZONE-2
SB #8 = CHINO ZONE-3

SB #9 = BUNKER HILL ZONE-1
SB #10 = ARLINGTON
SB #11 = COLTON
SB #12 = CUCAMONGA
SB #13 = POMONA
SB #14 = UPPER TEMESCAL
SB #15 = CLAREMONT HEIGHTS
SB #16 = LYTLE CREEK BASIN

[1] Data from Reference 44

Legend: Q&C - Quantity (Acre-Feet) & Total Dissolved Solids Concentration (mg/l)

TABLE 13[1]

PROJECTIONS BY SUBBASIN OF THE VOLUME
AND CONCENTRATION OF STREAM FLOW DIVERTED
FOR ARTIFICIAL RECHARGE WHICH REACHES THE
GROUND WATER RESERVOIR UNDER
THE UPPER SANTA ANA RIVER WATERSHED

YEAR	SB # 1	Q&C	SB # 2	Q&C	SB # 3	Q&C	SB # 4	Q&C	SB # 5	Q&C	SB # 6	Q&C	SB # 7	Q&C	SB # 8	Q&C
1980	185.	200.	0.	0.	0.	0.	0.	0.	14146.	269.	0.	0.	0.	0.	0.	0.
1985	185.	200.	0.	0.	0.	0.	0.	0.	14146.	269.	5000.	200.	0.	0.	0.	0.
1990	185.	200.	0.	0.	0.	0.	0.	0.	14146.	269.	15000.	200.	0.	0.	0.	0.
1995	185.	200.	0.	0.	0.	0.	0.	0.	14146.	269.	15000.	200.	0.	0.	0.	0.
2000	185.	200.	0.	0.	0.	0.	0.	0.	14146.	269.	15000.	200.	0.	0.	0.	0.

YEAR	SB # 9	Q&C	SB #10	Q&C	SB #11	Q&C	SB #12	Q&C	SB #13	Q&C	SB #14	Q&C	SB #15	Q&C	SB #16	Q&C
1980	1657.	270.	0.	0.	0.	0.	6339.	200.	0.	0.	0.	0.	5324.	200.	5561.	200.
1985	1657.	270.	0.	0.	0.	0.	6339.	200.	0.	0.	0.	0.	5324.	200.	5561.	200.
1990	1657.	270.	0.	0.	0.	0.	6339.	200.	0.	0.	0.	0.	5324.	200.	5561.	200.
1995	1657.	270.	0.	0.	0.	0.	6339.	200.	0.	0.	0.	0.	5324.	200.	5561.	200.
2000	1657.	270.	0.	0.	0.	0.	6339.	200.	0.	0.	0.	0.	5324.	200.	5561.	200.

SB #1 = CHINO ZONE-1
SB #2 = TEMESCAL
SB #3 = RIVERSIDE
SB #4 = RIALTO
SB #5 = BUNKER HILL ZONE-2
SB #6 = SAN TIMOTEO
SB #7 = CHINO ZONE-2
SB #8 = CHINO ZONE-3

SB #9 = BUNKER HILL ZONE-1
SB #10 = ARLINGTON
SB #11 = COLTON
SB #12 = CUCAMONGA
SB #13 = POMONA
SB #14 = UPPER TEMESCAL
SB #15 = CLAREMONT HEIGHTS
SB #16 = LYTLE CREEK BASIN

[1] Data from Reference 44

Legend: Q&C - Quantity (Acre-Feet) & Total Dissolved Solids Concentration (mg/l)

TABLE 14[1]

PROJECTIONS BY SUBBASIN OF THE
VOLUME AND CONCENTRATION IMPORTED
FOR RECHARGE WHICH REACHES THE
GROUND WATER RESERVOIR UNDER
THE UPPER SANTA ANA RIVER WATERSHED

YEAR	SB # 1	Q&C	SB # 2	Q&C	SB # 3	Q&C	SB # 4	Q&C	SB # 5	Q&C	SB # 6	Q&C	SB # 7	Q&C	SB # 8	Q&C
1980	28800.	260.	0.	0.	0.	0.	8000.	260.	0.	0.	0.	0.	0.	0.	0.	0.
1985	36290.	260.	0.	0.	0.	0.	7000.	260.	4999.	260.	0.	0.	0.	0.	0.	0.
1990	38200.	260.	0.	0.	0.	0.	7000.	260.	5000.	260.	0.	0.	0.	0.	0.	0.
1995	38900.	260.	0.	0.	0.	0.	7000.	260.	5000.	260.	0.	0.	0.	0.	0.	0.
2000	38900.	260.	0.	0.	0.	0.	7000.	260.	5000.	260.	0.	0.	0.	0.	0.	0.

YEAR	SB # 9	Q&C	SB #10	Q&C	SB #11	Q&C	SB #12	Q&C	SB #13	Q&C	SB #14	Q&C	SB #15	Q&C	SB #16	Q&C
1980	3000.	260.	0.	0.	2000.	260.	2000.	260.	0.	0.	0.	0.	0.	0.	0.	0.
1985	3000.	260.	0.	0.	5000.	260.	10100.	260.	0.	0.	0.	0.	0.	0.	0.	0.
1990	3000.	260.	0.	0.	5000.	260.	10100.	260.	0.	0.	0.	0.	0.	0.	0.	0.
1995	3000.	260.	0.	0.	5000.	260.	12100.	260.	0.	0.	0.	0.	0.	0.	0.	0.
2000	3000.	260.	0.	0.	5000.	260.	12100.	260.	0.	0.	0.	0.	0.	0.	0.	0.

SB #1 = CHINO ZONE-1
SB #2 = TEMESCAL
SB #3 = RIVERSIDE
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SB #5 = BUNKER HILL ZONE-2
SB #6 = SAN TIMOTEO
SB #7 = CHINO ZONE-2
SB #8 = CHINO ZONE-3

SB #9 = BUNKER HILL ZONE-1
SB #10 = ARLINGTON
SB #11 = COLTON
SB #12 = CUCAMONGA
SB #13 = POMONA
SB #14 = UPPER TEMESCAL
SB #15 = CLAREMONT HEIGHTS
SB #16 = LYTLE CREEK BASIN

[1] Data from Reference 44

Legend: Q&C - Quantity (Acre-Feet) & Total Dissolved Solids Concentration (mg/l)

TABLE 15[1]

Historical Relationship Between Precipitation and Deep Percolation
Santa Ana Region

Water Year	Precipitation MAF	Precipitation Inches[2]	Percolation MAF	Percolation Inches[3]
1950-51	0.305	8.8	0.0141	0.47
52	0.886	25.6	0.2893	9.70
53	0.421	12.1	0.0401	1.34
54	0.534	15.4	0.1322	4.43
55	0.443	12.8	0.0431	1.44
56	0.461	13.3	0.0960	3.22
57	0.431	12.4	0.0534	1.79
58	0.912	26.3	0.2516	8.45
59	0.229	6.6	0.0184	0.62
60	0.359	10.4	0.0265	0.89
Average		14.4		3.25

[1] Data from References 27, 28
[2] Water Bearing Area = 416,100 acres
[3] Area of Nodal Pattern = 356,000 acres
MAF = Million Acre-Feet

5.2.5 Other Assumptions

The following additional assumptions have been made for the calculations of total percolate concentration:

1. Uniform and complete mixing of wastewater and deep percolate in time and space
2. Full conversion of all forms of nitrogen to nitrate
3. Negligible lateral flow of wastewater

5.2.6 Nitrate-N Concentration in the Total Percolate, N_{tp}

$$N_{tp} = \frac{(N_{ww})\ (WW_L) + (N_{DP})\ (DP)}{(WW_L + DP)} \qquad (1)$$

If we assume that:

N_{ww} = 17.74 mg/l (75 gpcd wastewater flow; 0% denitrification (sec. 5.2.1))

WW_L = 12.5 in/yr (150 gal/day wastewater flow; 7,000 sq. foot lot size (sec. 5.2.2))

N_{DP} = 1.0 mg/l (sec 5.2.4)

DP = 3.25 in/yr (sec 5.2.3)

Then $$Ntp = \frac{(17.74)\ (12.5) + (1.0)\ (3.25)}{(12.5 + 3.25)} = 14.29 \text{ mg/l}$$

As discussed previously and shown in Table 9, the wastewater loading rate (WW_L) is affected significantly by lot size as well as wastewater flow. If we assume a 20,000 sq. foot lot size, rather than 7,000 sq. foot as above, the resultant value for WW_L is 4.4 in/yr (see sec. 5.2.2). This change in WW_L in turn significantly affects N_{tp}:

$$Ntp = \frac{(17.74)\ (4.4) + (1.0)\ (3.25)}{(4.4 + 3.25)} = 10.63 \text{ mg/l}$$

Thus, for a 20,000 sq-foot lot, and for the values assumed above, the nitrate-N concentration of the total percolate is very close to the drinking water action level of 10 mg/l.

Table 9 shows the results for N_{tp} based on different assumptions of lot size and wastewater flow. It is evident that lot size, or the density of development, is a critical factor in determining the impacts to ground water quality of septic systems.

As shown in preceding sections, there is a range of possible values for the variables in Equation 1. Figure 5 represents graphically the solutions of Equation 1 using a range of values for denitrification (this affects N_{ww} (see Table 8)) and wastewater loading rates (WW_L) (see Table 9). These graphical solutions provide useful information to evaluate water quality impacts from septic systems. It is clear from the graphical plots that the greatest potential for ground water nitrate problems arises in areas where the ratio of wastewater to deep percolation is high (i.e. areas of low rainfall and high density developments on septic systems). It is clear that, for high density developments, the 10 mg/l nitrate-N limit can be easily exceeded. Again, this demonstrates that the density of development is a critical factor in determining septic system impacts on ground water.

5.3 Nitrate Concentration in Ground Water

The septic system effluent and the recharge waters (total percolate) migrate through the soil into the underlying ground water. Let us examine the impact of the total percolate on ground water quality under various scenarios:

<u>Scenario 1.</u> **Small lots, N_{tp} greater than 10 mg/l; ground water nitrate-N greater than 10 mg/l**

For ground water subbasins with no assimilative capacity and where the nitrate concentration already exceeds the drinking water action level, high density developments on small lots (N_{tp} greater than 10 mg/l, see sec 5.2.6) will add to the nitrate problem.

<u>Scenario 2.</u> **Small lots, N_{tp} greater than 10 mg/l; ground water nitrate-N less than 10 mg/l**

If the ground water nitrate levels are lower than that of the total percolate, dilution of the total percolate by ground water can be expected. Due to the slow mixing of the percolate with ground water (laminar flow regime), most of the percolate will be confined to the upper portions of the aquifer. In this case, the percolate will slowly degrade the existing ground water quality.

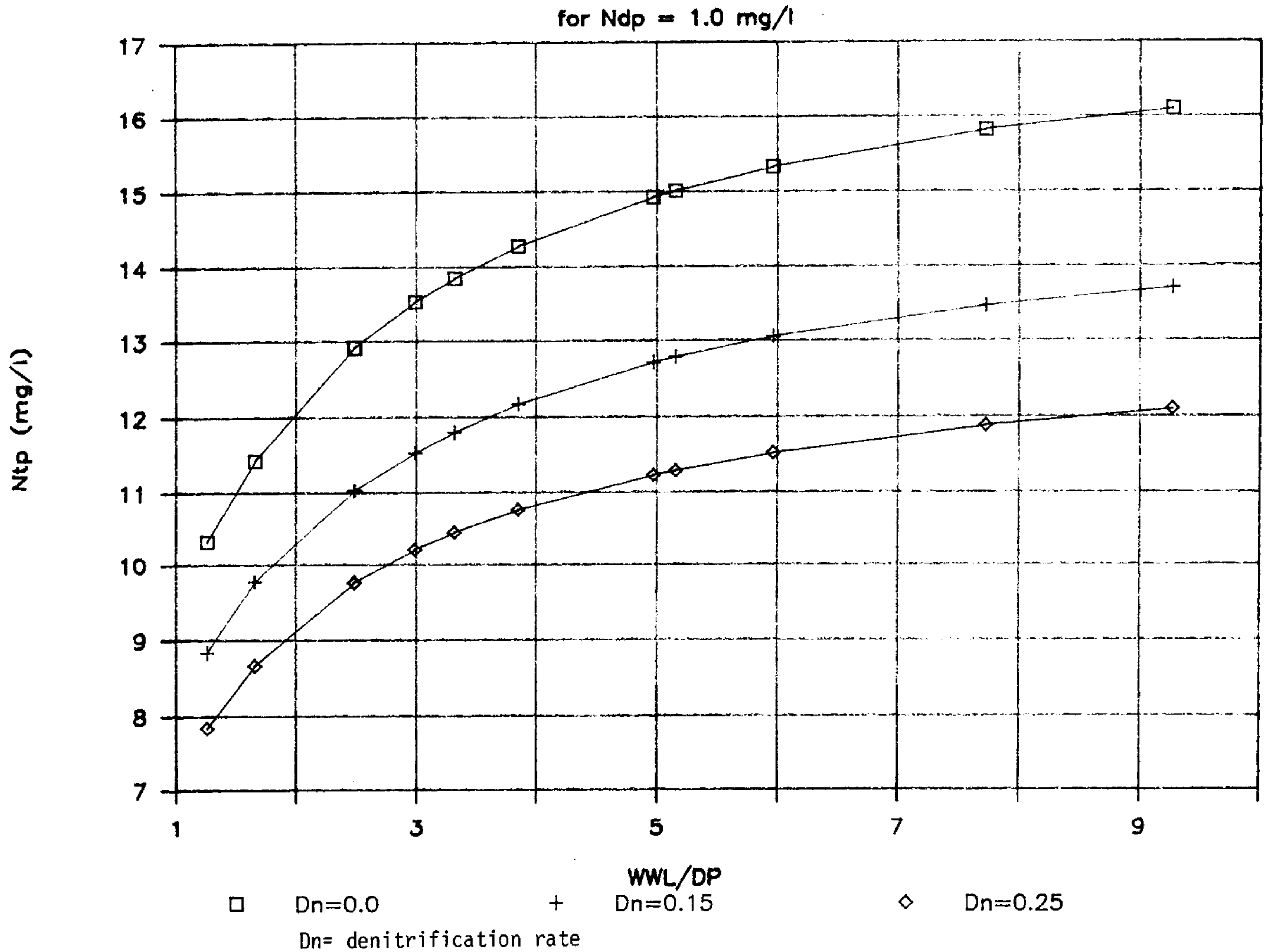
<u>Scenario 3.</u> **Large lots, N_{tp} less than or equal to 10 mg/l; ground water nitrate-N greater than 10 mg/l**

On the contrary, the percolate from developments on large lots (N_{tp} less than 10 mg/l, see Sec. 5.2.6) will not cause a further violation of the drinking water action levels. The ground water quality will gradually improve.

<u>Scenario 4.</u> **Large lots, N_{tp} less than or equal to 10 mg/l; ground water nitrate-N less than 10 mg/l**

There will be no violation of the drinking water action level. Thus, the critical development density (see Sec. 5.4) is the most important factor in controlling nitrate loading to ground water.

FIGURE 5 Ntp Vs. WWL/DP



5.4 Critical Development Density (D_c)

The critical development density (Dc) is the septic system density which will result in a total percolate nitrate-N concentration of 10 mg/l. This density is calculated using Equation 2 (43):

$$Dc = \frac{(2.01)\ (N_{ww} - 10)}{(DP)\ (10 - N_{DP})} \qquad (2)$$

where Dc = Critical development density in acres per dwelling unit

N_{ww} = Nitrate-N in the wastewater adjusted for denitrification losses (see Section 5.1.3)
DP = Deep percolate (see Section 5.2.3)
N_{DP} = Nitrate-N of deep percolate (see Section 5.2.4)

A typical calculation is shown below:

If we assume that:

N_{ww} = 17.74 mg/l (Mass Loading of 6 gm/c/d, 0% Denitrification Rate, and Wastewater Flow of 75 gal/c/d)
DP = 3.25 in/yr
N_{DP} = 1.0 mg/l

Then
$$D_c = \frac{(2.01)\ (17.74-10)}{(3.25)\ (10-1.0)}$$

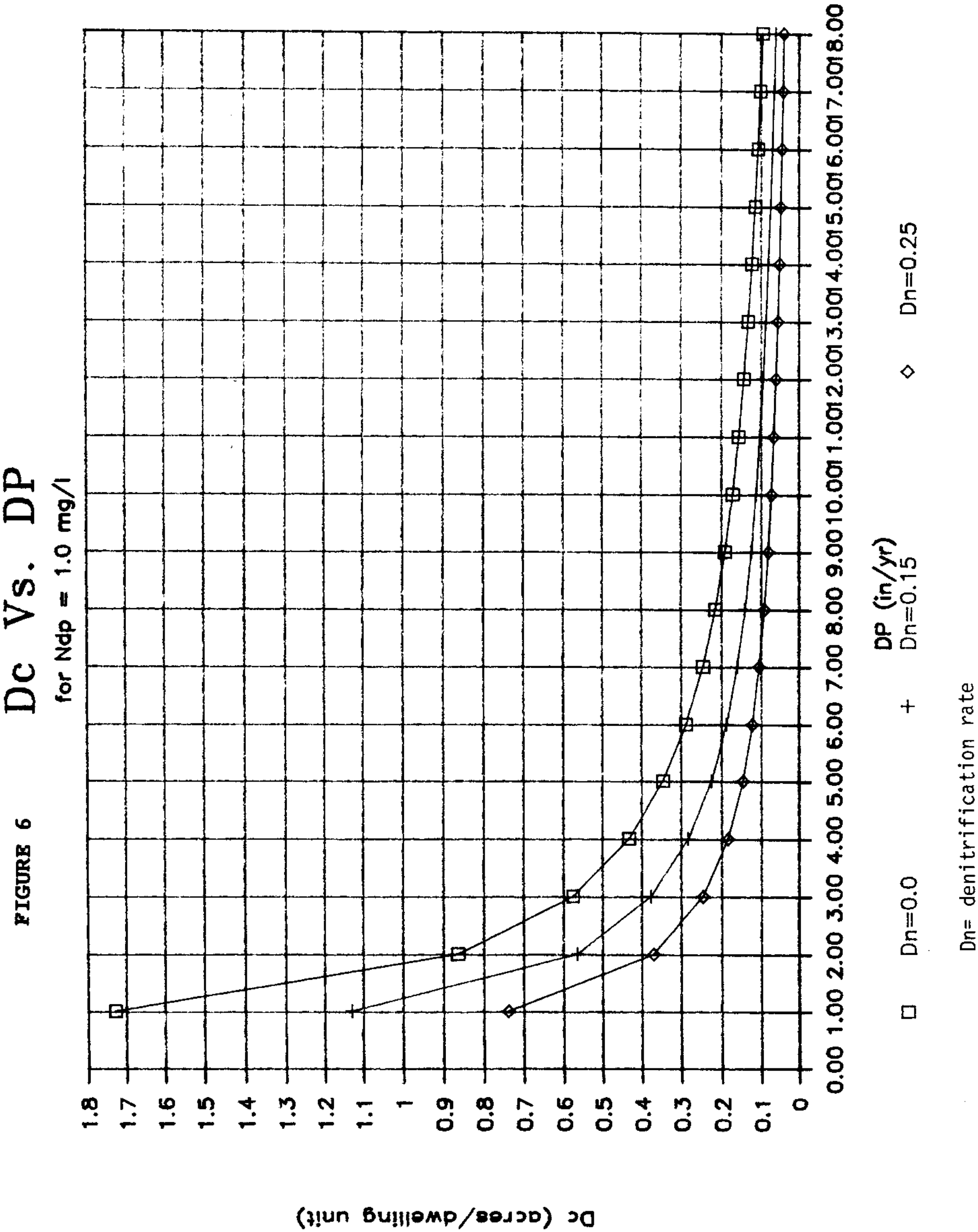
$$= 0.53 \text{ acre/dwelling unit (ac/du)}$$

If N_{ww} is 17.74 then the critical density would be 0.5 acre/dwelling unit. The critical densities calculated using a range of values for N_{ww} are shown in Table 8. It is clear that in order to avoid percolate nitrate-N concentrations in excess of 10 mg/l (the drinking water standard) under the assumed conditions, the minimum lot size which should be required for septic system use is 0.5 acre. It must be emphasized, however, that the calculated critical development density is dependent on the values assumed for each of the variables in Equation 2; as discussed previously, there is a range of acceptable values for each of these variables. The critical development densities which are calculated using a range of deep percolate (DP) and denitrification rates (remember, that the rate of denitrification affects N_{tp}) (see Section 5.2.6) are shown graphically in Figure 6. It can be seen from this figure that as the deep percolate and denitrification rates increase, conditions for septic tank system use without water quality impacts improve and the critical development density becomes less stringent. But at lower denitrification and deep percolate rates the converse is true.

Table 8 summarizes the critical development density for a whole range of nitrogen mass loading rates, denitrification rates, and wastewater flow rates. The values used here for mass loading rates, denitrification rates, and flow rates cover the range generally reported in the literature. Some of these values are not representative of conditions in this Region; e.g. in Fontana-Bloomington area where seepage pits are extensively used on small lots in sandy soils, the loss due to denitrification would be negligible. Thus a critical development density of 0.23 or 0.35 acre/dwelling unit shown in Table 8 would not occur. Additionally, a nitrogen mass loading rate of 17 gm/c/d with a wastewater flow rate of 25 gal/c/d and 0% denitrification rate (D_c = 9.67 acres/dwelling unit) is unrealistic for conditions in this Region.

From the above considerations, it appears that the absolute minimum lot size required for septic system use without adversely impacting ground water subbasins in the Region should be 0.5 acre/dwelling unit (also see Sec. 7.0).

FIGURE 6


Dc Vs. DP
for Ndp = 1.0 mg/l
Dc (acres/dwelling unit)
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00 11.00 12.00 13.00 14.00 15.00 16.00 17.00 18.00
DP (in/yr)
Dn=0.0
Dn=0.15
Dn=0.25
Dn= denitrification rate

Thus, if critical development density is considered as a control measure for addressing the nitrate problem, then the minimum lot size should be 1/2 acre per dwelling unit. There are other control options that could be considered for eliminating, minimizing, and/or controlling the nitrate loading to the ground water subbasins from septic tank effluent.

6.0 SEPTIC SYSTEM CONTROL OPTIONS

As discussed in some detail at the April workshop, the method of mitigating the cumulative impacts of septic systems which is generally recommended in the literature is the establishment of maximum allowable densities (or minimum lot sizes). This and a number of other control options are described below:

6.1 Minimum lot size requirements:

As illustrated above, critical development densities (minimum lot sizes) for septic system use can be calculated using various assumptions of deep percolation, nitrate-N concentrations in the effluent, denitrification of septic system effluent, and other variables. All of these variables translate into the total percolate nitrate-N concentration which affects the underlying ground water. Using relatively liberal values for these variables in the calculations, the minimum lot size necessary to protect water quality is 1/2 acre per dwelling unit. Calculations based on more conservative assumptions for the variables indicate that greater lot sizes are necessary (see Table 8).

Lot size clearly affects not only water quality impacts but the economics of housing development as well. In selecting a minimum lot size requirement to protect water quality, some consideration of economic reasonableness must also be given.

6.2 Lot size restrictions with additional conditions

In some areas, the conditions may be well suited for septic systems. A case-by-case analysis of deep percolation rates (more recharge provides greater dilution of the septic tank effluent), soil conditions (higher denitrification in clay matrix or very fine soil) and other conditions would be required to calculate critical development density. The Regional Board could adopt exemption criteria for special conditions under which other lot sizes could be used in these areas. This would require substantial additional staff resources for a case-by-case analysis.

Again, it is clear from the preceding analysis that septic system use on lot sizes less than 0.5 acre will result in unacceptable water quality impacts. It is possible that a more stringent lot size requirement would be appropriate in some areas.

6.3 Use of Innovative Systems

A literature survey by the Staff indicates that there are no cost-effective methods currently available for denitrification of septic tank effluent. Staff has approved some low-cost experimental systems in the region. The effectiveness of these systems is yet to be proven. If proven to be successful, these systems could be approved for denitrification of septic tank effluent. Again, such systems are not likely to be feasible on a large scale from an economic standpoint.

6.4 Require mitigation measures to comply with water quality objectives

A septic system user could participate in alternate mitigation measures which would assure compliance with water quality objectives. Several waste dischargers in the region participate in such offset programs. However, this may not be a feasible option for an individual on-site sewage disposal system user.

6.5 Waste Discharge Prohibition

The Regional Board adopted waste discharge prohibitions on the use of septic tank systems in several areas of the Region. Most of these areas had documented public health problems resulting from on-site sewage disposal systems. These problems stemmed from surfacing of septic system effluent, seepage of effluent into flowing streams, high ground water, and shallow bedrock conditions. These conditions could be easily documented in accordance with Section 13280 through 13284 of the Water Code to justify a discharge prohibition. There were also important concerns about nitrate contamination of ground water in many of these areas. With an available option of limiting septic system densities, a discharge prohibition option is not justifiable, and staff does not consider this to be a viable option.

6.6 Other Control Options

A number of other options such as extension of sewers by developers, building moratoria by local agencies and package treatment plants were discussed in the April 14, 1989 Staff Report.

Staff believes that, in order to minimize water quality impacts associated with subsurface disposal systems, every effort should be made by local agencies to ensure the provision of sewer lines (and treatment facilities) for high density developments.

7.0 Conclusion

The critical development density calculated for all possible scenarios range from 0.23 to 9.67 acres/dwelling unit (see Table 8). As discussed in Section 5.4, some of these scenarios are not representative of conditions in this Region. Virtually all factors considered for calculation of critical development density vary with geographical location, water supply quality, hydrogeology of the area, socioeconomic status and number of appliances and their use. It is evident from Table 8 and from discussion above that it would be impossible to select "a lot size" that would assure equal water quality protection under all circumstances for the whole Region.

A minimum lot size of 9.67 acres/dwelling unit (see Table 8) would be a very conservative critical development density that would assure ground water protection. However, as indicated earlier, this would be an overkill in most areas of the Region. Additionally, this minimum lot size would impose severe economic constraints on developers and home buyers, and such a large lot size may not be necessary for conditions in this Region for reasonable water quality protection.

If we consider the most liberal assumptions, the minimum lot size is 0.5 acre/dwelling unit. An extensive literature search by Regional Board staff has also indicated that the minimum lot size recommended in the literature for septic system use is 0.5 acre. In many areas of the Region, the volume of deep percolate would be higher than the average value (3.25 in/yr) used in the calculation of critical development density. Also, even in high density developments some areas (playgrounds, parks, etc.) would not be paved. These factors were not considered in the calculation of critical development density. Thus, considering all the factors, it appears that a minimum lot size of 0.5 acre/dwelling unit would provide reasonable water quality protection for most areas of the Region.

As indicated in Section 2.5, most ground water subbasins in the Region have some problems with high nitrates. A more comprehensive study of the ground water subbasins is currently underway as part of the Basin Plan Update work. That study is expected to identify the ground water subbasins with no assimilative capacity for nitrate. If a minimum lot size of 0.5 acre is adopted by the Board, the following surveillance program could be initiated to monitor the impact of septic systems on nitrate levels in the ground water:

1. Identify ground water subbasins with no assimilative capacity where large number of septic systems have been approved.

2. Select key monitoring wells in the area.

3. Conduct periodic sampling and analysis of ground water from the key wells for at least five years.

4. Review the data so generated; revise minimum lot size requirements if necessary.

For large high density developments in Fontana/Bloomington areas, such a program is already in place.

Regional Board staff feels that this is the most prudent approach for optimum water quality protection. Also, this (liberal) minimum lot size would not impose undue burden on the developers and home buyers.

8.0 STAFF RECOMMENDATION

Based on the information presented above and the testimony at the April 14, 1989 public workshop, staff believes that the best control option is the adoption of a minimum lot size requirement for subsurface disposal system use within the Region. To assure, at a minimum, optimum protection of ground water quality, the minimum lot size required for septic system use for new developments should be one-half acre (gross) per dwelling unit.

Staff recommends a Basin Plan amendment to include this minimum lot size requirement for developments using on-site septic tank subsurface leaching/percolation systems. Staff intends to present a resolution including such an amendment for the Board's consideration at the regular Board meeting on October 13, 1989.

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APPENDIX

California Regional Water Quality Control Board
Santa Ana Region

April 14, 1989

ITEM: 6

SUBJECT: A Review of the High Nitrate Problems in and around the Fontana and Bloomington Areas of San Bernardino County and Their Relationship to High Density Developments on Septic Tank-Subsurface Disposal Systems

DISCUSSION:

In the last few years, Fontana and Bloomington and nearby unincorporated areas in San Bernardino County have experienced tremendous increases in high density developments that utilize individual subsurface disposal systems (septic systems). Dramatic growth in these areas continues, with reliance on septic systems. The use of high density septic systems may be contributing to further degradation of ground water quality in these areas, especially with respect to nitrates.

Regional Board staff has conducted an extensive study of the literature on the impacts of high density septic systems on water quality, as well as a comprehensive review of technical data and several unpublished reports germane to this issue. Research results and documented cases of water quality degradation in the Santa Ana Region and other parts of the country have demonstrated that development density requirements or other control measures are necessary to prevent water quality degradation from septic systems.

Government agencies and academic institutions have conducted extensive research to establish the actual impacts of septic systems on ground and surface waters. The method of mitigating the cumulative impacts of septic systems which is generally recommended in the literature is the establishment of maximum allowable densities. Researchers establishing septic system density criteria for large, geologically and hydrologically heterogeneous areas recommend densities of no more than one system per half acre. This is the most liberal or lenient figure accepted. Most studies dealing with areas less than ideally suited to septic system waste disposal recommend densities closer to one system per five acres. Average septic system density in the Fontana-Bloomington area is one system per 0.17 acre (i.e. six systems per acre).

Sections 13225 and 13240 of the Porter-Cologne Water Quality Control Act charge the Regional Board with the responsibility to protect water quality and empower the Board to establish requirements to prevent water quality degradation in the Region. This authority includes the regulation of discharges from subsurface disposal systems.

Staff has identified a number of options available to address water quality problems related to high density septic system use in Fontana, Bloomington, and neighboring areas. Staff believes that careful review of these options is warranted, leading to the development of a recommended course of action which would be presented at a subsequent Board meeting.

I. Study Area

A. Location

The area under consideration for this review is shown on Figure 1. The area includes portions of Fontana, Bloomington, and nearby unincorporated areas. The area overlies the Chino I and II Ground Water Subbasins.

The communities in the study area are experiencing tremendous growth and are in the process of conversion from a rural pattern of land use to an urban one. Currently, the combined population of the City of Fontana and the Bloomington area is approximately 91,200. The present unsewered population in the area is approximately 22,400, contributing 2.02 million gallons per day of partially treated sewage to local ground water. At the present growth rate, the population in the area will be doubled by the year 1997. Incidentally, the Counties of San Bernardino and Riverside experienced the biggest growth in the nation during 1988, with a 22 percent increase in new housing projects.

B. Septic Systems in Rural Settings

The use of onsite subsurface sewage disposal systems has long been recognized as one of the most effective means of dealing with sanitary wastewater in rural settings. In sparsely populated areas, the availability of open land tends to minimize potential water quality or public health effects associated with such sewage disposal practices.

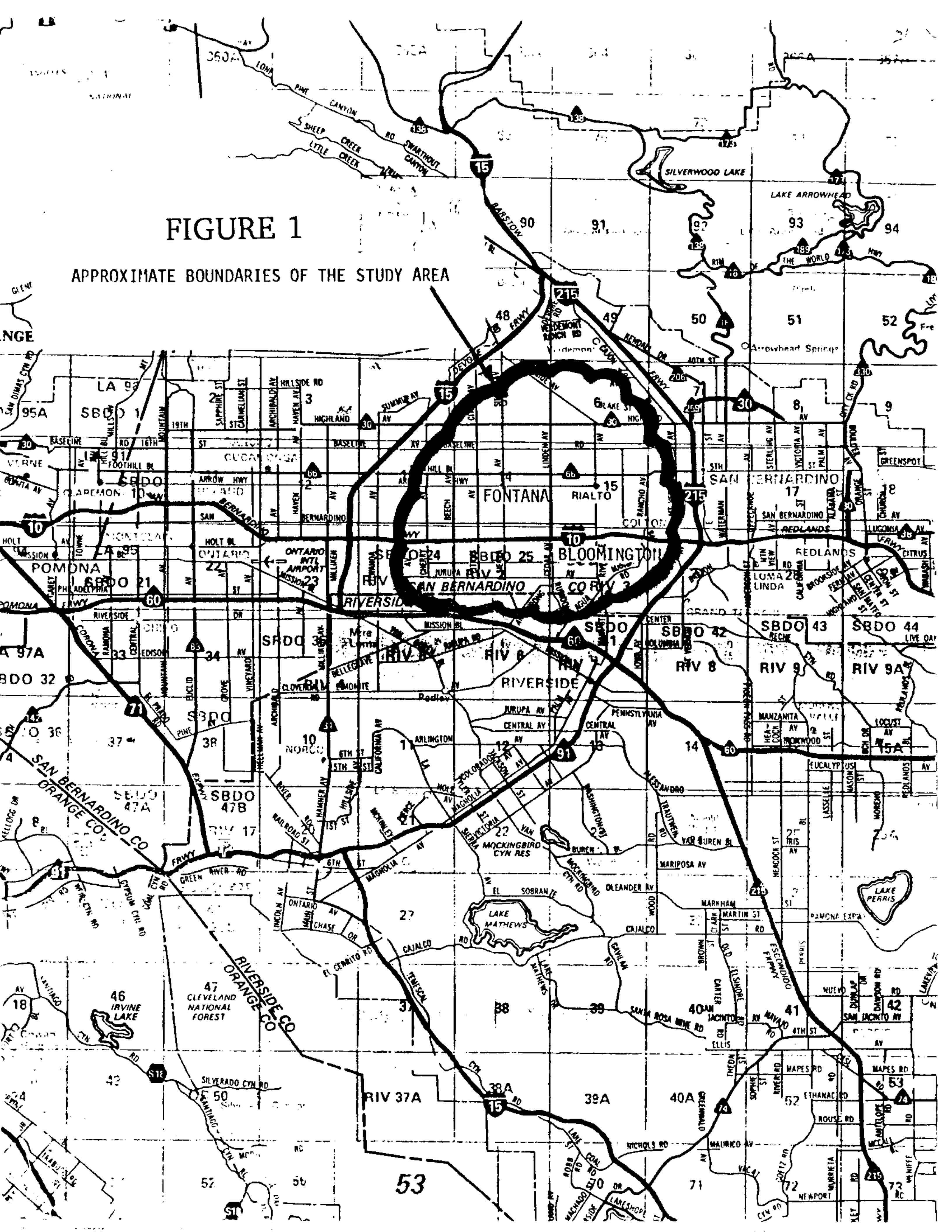


FIGURE 1

APPROXIMATE BOUNDARIES OF THE STUDY AREA

Small, unsewered communities are also tending more frequently to continue the use of septic tanks rather than to embark on major sewerage construction projects. If properly engineered, installed, and maintained, and if soil characteristics are right, individual septic systems can function effectively to dispose of human and household wastes in areas where community sewage treatment plants are cost-prohibitive because of low housing densities. Soil characteristics also play an important role in the treatment of wastewater discharged to the subsurface. As rural and urban fringe areas experience population and housing growth, however, the low density conditions which once made septic systems feasible disappear.

C. Septic Systems in Urban Areas

The transformation from a rural to an urban community normally means that homes and other structures are built closer together in order to economize on land costs and to facilitate the working of the community. Unfortunately, during this transformation, the change from individual sewage disposal to community service is often delayed or rejected on the basis of initial cost, disruption of services, roads and landscaping, or a professed lack of need.

Such cases have been documented nationwide and are as natural an occurrence as population growth or migration. Unfortunately, however, the resulting discharge from high density septic systems adversely impacts ground and surface waters.

Septic systems constitute a serious threat to ground water that serves as a drinking water source in many parts of the United States. The 1980 Census estimated that there are about 22 million septic systems operating in the United States, serving nearly one-third of the nation's population. Together, about one trillion gallons of wastewater is discharged from these systems to our soils and ground water every year, a sobering thought given that 50 percent of all drinking water used in the United States is ground water. However, for many, especially in rural areas, onsite waste management is the only practical solution to waste disposal needs.

D. Sewer Service in the Study Area

Sewer service has lagged behind new residential, commercial, and industrial developments in the study area. The area under consideration is within the service boundaries of either the City of Fontana or the City of Rialto (Figure 2). The wastewater collected by the City of Fontana is treated at the Chino Basin Municipal Water District's Regional Plant No. 1. The City of Rialto has its own wastewater treatment plant. These wastewater treatment plants are currently undergoing expansion and are expected to have enough capacity to accept wastewater from the study area. However, the wastewater collection agencies have not been able to keep pace to provide sewer lines to the new developments in the area. The area in which new, high density developments on septic systems have been approved within the last five years is delineated in Figure 3. Most of this is within the unincorporated area of San Bernardino County. Unfortunately, these developments overlie an area which is known to have high levels of nitrate in ground water.

II. Ground Water

The buildup of nitrate in ground water is potentially one of the most significant long-term consequences of onsite sewage disposal practices. With each new proposal for development utilizing septic systems, there is a growing need to quantify and evaluate the possible changes in ground water quality that may result.

Due to the slow, downward migration of septic effluent through soil, the adverse individual and cumulative impacts of septic tank systems on the local ground water may not be known until pollution has already occurred. As ground water in the study area is an average 400 feet deep, it may take several years, in some places, for the impacts of high density septic systems to be observed.

Once it has reached ground water, nitrate appears to be quite stable. The filtering action of soil removes bacteria and most organic matter so that there can be little biological activity that might remove or transform nitrate once it has reached ground water. Because of the slow movement of ground water, nitrate contamination problems may take 20 to 100 years to correct, if ever.

By the time water quality problems in some sections of the study area are documented, there are likely to be serious and perhaps irreversible nitrate problems in the area.

FIGURE 2

APPROXIMATE SERVICE BOUNDARIES OF CITIES OF FONTANA AND RIALTO

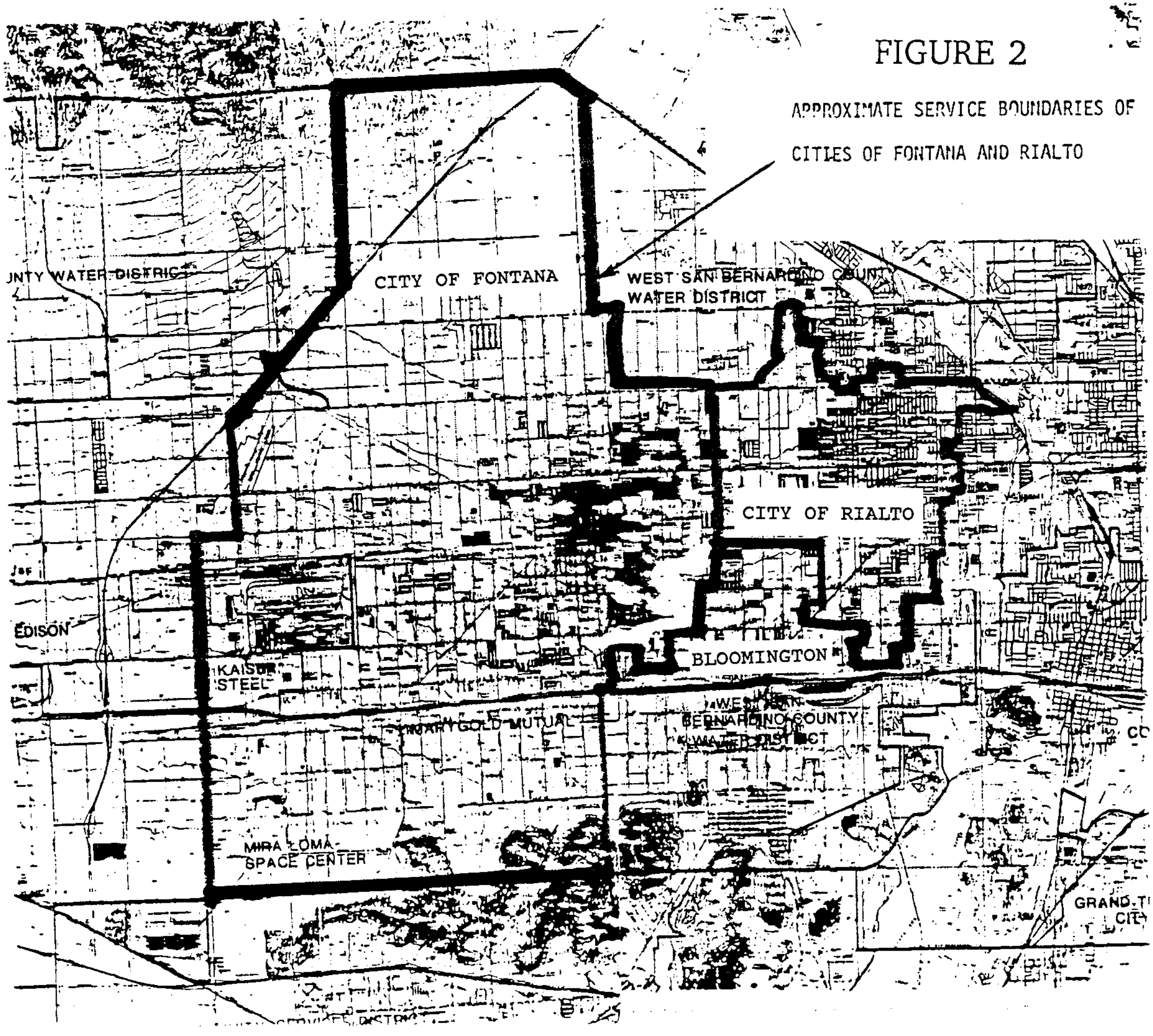
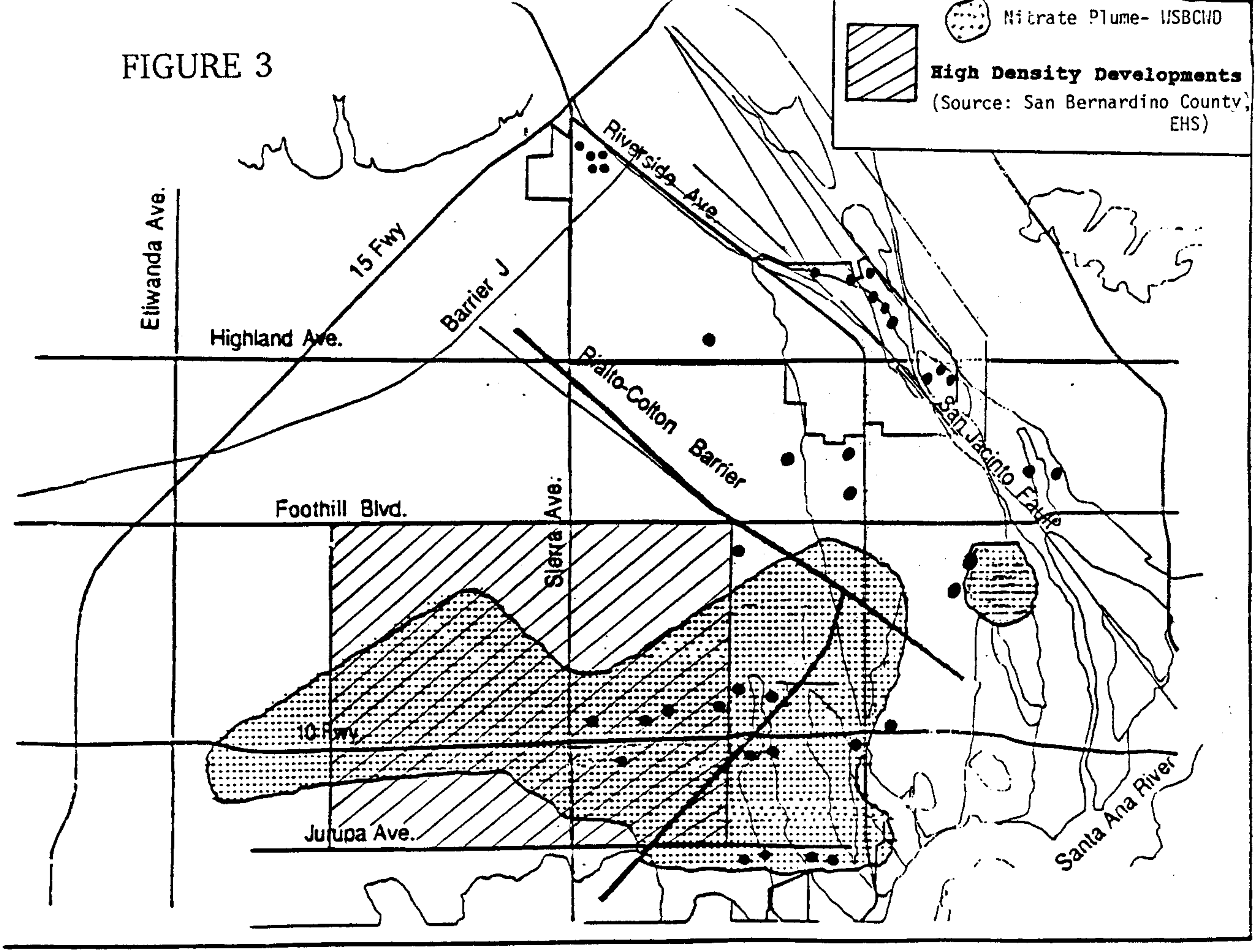


FIGURE 3


Nitrate Plume- USBCWD
High Density Developments
(Source: San Bernardino County, EHS)
Eliwanda Ave.
15 Fwy
Barrier J
Riverside Ave.
Highland Ave.
Rialto-Colton Barrier
San Jacinto Fault
Foothill Blvd.
Sierra Ave.
10 Fwy
Jurupa Ave.
Santa Ana River

As noted above, ground water contamination by septic system effluent is difficult to recognize and measure until significant degradation has already occurred. Again, this is due, in part, to the slow downward migration of effluent through the soil and rock. It is also due to the initial accumulation of effluent contamination near the ground water level from which very few water wells draw their supplies.

It is generally accepted that wells which overlie and penetrate deeper portions of a ground water basin generally produce water lower in contaminants than shallow wells in the same area. As the source of contamination is from the land surface, deeper aquifers are somewhat isolated from the overlying contaminants by impermeable aquicludes (i.e. silts and clays). In other words, contaminants entering the ground water through deep percolation are likely to be confined to the upper horizons. Therefore, vertical contamination tends to decrease with depth. The contamination in the Fontana and Bloomington areas is believed to concentrate in the upper 300 feet or so of saturated thickness.

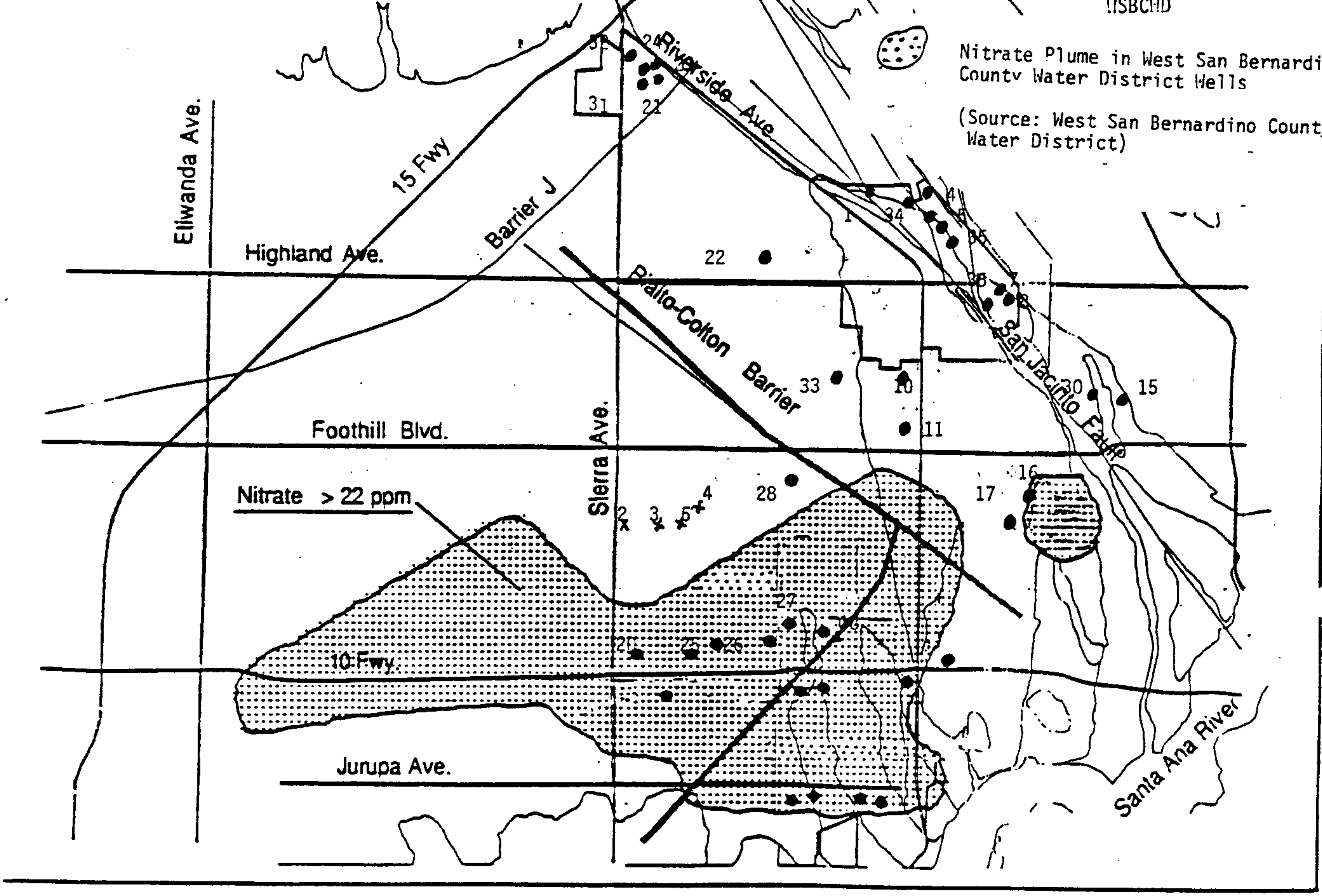
A. Nitrate Quality in the Study Area

There are several domestic water supply wells in the study area (see Figure 4). The water purveyors in the area have provided Board staff with water quality data for these wells; this data is summarized in Table 1. Some of these wells have been taken out of service due to high nitrate levels. The primary drinking water standard for nitrate is 45 mg/l as nitrate (this is equivalent to 10 mg/l as nitrogen). Approximately 48 percent of the test results of the wells in the study area indicate nitrate levels exceeding the primary drinking water standard. The highest level of nitrate detected in the area is in the West San Bernardino County Water District's well No. 27 (89 mg/l as nitrate). The area that has nitrate concentration greater than 22 mg/l is delineated in Figure 4. Limited data suggests that there has been an increasing trend over time of nitrate levels in ground waters of the area.

B. Causes of Nitrate Problems

The cause(s) of high nitrate problems in the study area are not fully understood. However, it is generally believed that these problems are due to a combination of past fertilizer use in the area and wastewater discharges to subsurface disposal systems.

FIGURE 4



x- well location, [illegible] Gold Mutual
● —Well Location
USBCHD
Nitrate Plume in West San Bernardino County Water District Wells
(Source: West San Bernardino County Water District)
15E Fwy
15 Fwy
Riverside Ave
Barrier J
Rialto-Colton Barrier
San Jacinto Fault
Ellwanda Ave.
Highland Ave.
Foothill Blvd.
Sierra Ave.
Nitrate > 22 ppm
10 Fwy.
Jurupa Ave.
Santa Ana River

TABLE 1

WATER QUALITY DATA

Water Purveyor	Well No.	Sampling Date	Nitrate Level as NO_3 (mg/l)
West San Bernardino County Water District	20	January 1988	80.7
	25	May 1976	58.0
	26	March 1968	70.0
	27	April 1976	89.0
	28	March 1976	76.0
	29	February 1988	34.0
	Raney	February 1988	55.0*
	Bruno	October 1987	47.0
Fontana Water Company	11	1988	12.0*
	13	1986-87	21.0*
	16	1986-87	33.3*
	20	1986-87	31.5*
	21	1986-87	50.1*
	22	1986-87	19.8*
	35	1986-87	20.0*
	38	1986-87	26.6*
Marygold Mutual Water Company	2	1976	50.0*
	3	1976	42.0
	4	1978	56.5*
	5	1987	65.0*
	8	1986-87	26.9*

*Average value during a month or a year

1. Fertilizer Use

For several years the area was used for citrus, vineyards and irrigated crops. Fertilizers used in agriculture are known to contribute to nitrate problems in ground water.

2. Wastewater Discharges from Septic Systems

a) Nitrogen Contributions from Septic Systems

Nitrogen is present in high concentrations in several forms in septic tank effluent. The components are ammonium-nitrogen (55-65 percent) and organic nitrogen. Total nitrogen concentrations have been reported to vary from 20 mg/l to as much as 100 mg/l as N, with the average generally in the range of 35 to 45 mg/l as N (see Table 2). It is estimated that the typical annual nitrogen contribution from a family of four is about 33 kg, or more than 200 times the amount that would be introduced naturally from precipitation and mineralization of soil organic nitrogen (transformation of organic nitrogen to nitrate).

b) Nitrogen Transformations

Upon introduction to the soil through subsurface disposal fields, nitrogen may undergo various transformations, including nitrification and denitrification (see Figure 5).

Nitrification may be broadly defined as the biological conversion of nitrogen in organic or inorganic compounds from a reduced to a more oxidized state. The predominant end product is nitrate (NO_3). Denitrification refers to the biological or chemical reduction of nitrate and nitrite (NO_2) to volatile gases, usually nitrous oxide or molecular nitrogen or both. These transformations are largely dependent on soil conditions, including soil type, temperature, moisture, and oxygen content.

The organic and ammonia nitrogen in septic tank effluents are adsorbed to soil particles within short distances. Under anaerobic soil conditions (i.e., no free oxygen) little nitrification (conversion to nitrate) of these compounds occurs. However, under favorable moisture, temperature, and oxygen conditions such as generally occur in well-drained soils (as found in the study area), soil bacteria will oxidize organic and ammonia nitrogen to nitrate. Virtually complete nitrification of ammonium-nitrogen has been found to take place in the unsaturated zone in well-aerated soil below septic tank disposal fields.

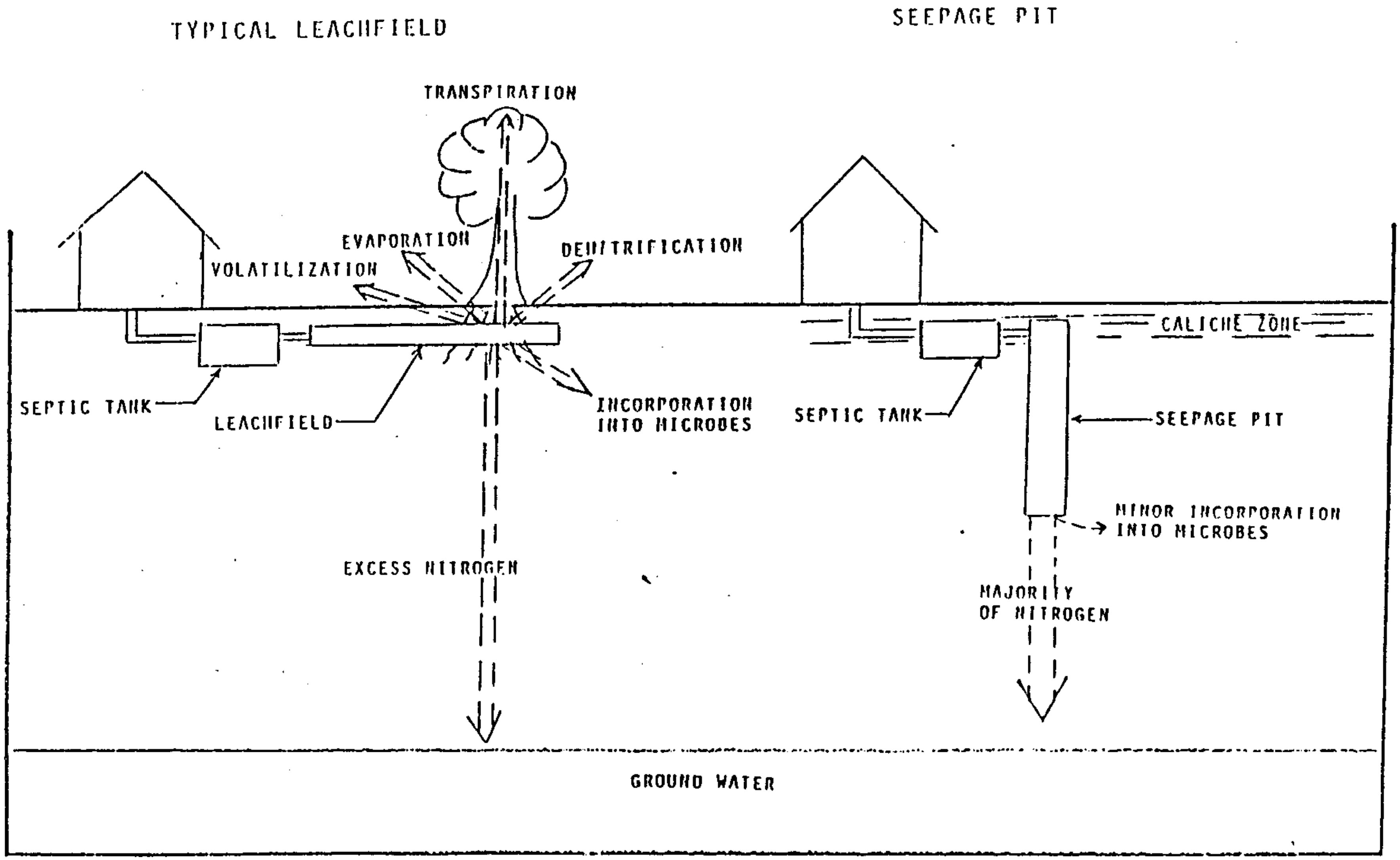
TABLE 2

TYPICAL NITROGEN COMPOSITION OF UNTREATED DOMESTIC WASTEWATER [25]

Constituent	Concentration (mg/l)		
	Strong	Medium	Weak
Nitrogen (total as N):	85	40	20
Organic	35	15	8
Free Ammonia	50	25	12
Nitrites	0	0	0
Nitrates	0	0	0

FIGURE 5[11]

FATE OF NITROGEN WITH SUBSURFACE DISPOSAL



Nitrogen balance studies indicate that denitrification is relatively insignificant in deep sandy soils such as those found in the study area.

Nitrate is more mobile in soil than ammonia or organic nitrogen, and is essentially unaffected by movement through most soils. Removal of nitrate by plants or through microbial uptake into biomass may occur to a limited extent, but these are generally considered to be insignificant nitrate sinks.

In summary, then, in well-aerated soils such as are found in the study area, essentially all of the organic and ammonia nitrogen discharged from septic systems is transformed to nitrate and passes easily through soils, together with percolating effluent and other recharge waters, to ground water.

In sandy soils which are conducive to nitrate migration to ground water, the only active mechanism for lowering the nitrate content of septic effluent is by dilution with uncontaminated water. As discussed below, there is only a limited amount of uncontaminated dilution water available from precipitation.

Two factors contribute to nitrate problems in the study area: the unique hydrogeology of the area and climate.

<u>i) Hydrogeology</u>

Natural ground water recharge to the area is from the Lytle and Cajon creek areas. Flow is southerly to the Jurupa mountains where impermeable bedrock forces the water to move either east, below the Colton narrows, or west around the mountains near Etiwanda avenue. The result of this ground water flow pattern is the concentration of a "mound" of nitrates north of the Jurupa mountains, i.e. within the study area.

As discussed below, the soil characteristics of the study area are conducive to the contamination of ground water by septic system effluents.

Two types of soils in the study area are:

1. Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well drained sands or gravels. These soils have a high rate of water transmission and low runoff potential.

2. Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained sandy-loam soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

These types of soils are suitable for nitrate migration to the ground water.

The average depth to ground water is approximately 300 to 400 feet below ground surface. In general, depth to ground water changes with local changes in topography. Average static water level in the area is approximately 438 feet. Well logs indicate fine-grained materials at various depths ranging from 9 to 346 feet.

ii) Climate

Climate in the area is semiarid, characterized by warm, dry summers, low precipitation, and mild winters. Mean annual precipitation is about 12.5 inches. More than two-thirds of this rainfall occurs from December through March, with approximately 90 percent occurring between November and April. Thus, in most months of the year, there is very little dilution of the wastewater and in-situ ground water from precipitation.

C. Impacts of Nitrates on Water Resources

Nitrate and total dissolved solids (TDS) are the most common mineral constituents found to impact Southern California ground water basins. Approximately 87 percent (43,000 acre-feet per year) of the Metropolitan Water District of Southern California's ground water production loss is due to nitrate and TDS. Eighty-nine wells in the Chino Ground Water Basin, which includes the study area, have nitrate levels above drinking water standards. Absent high nitrates, ground water in the study area would provide a good source of water supply.

As noted earlier, several wells in the study area have been removed from service due to high nitrate levels. Some of the water agencies in the area occasionally blend the high nitrate water with low nitrate water from other sources. Ground water from some of the wells is not suitable for blending due to extremely high levels of nitrate. If appropriate control measures are not implemented in a timely manner, many more wells will have to be taken out of service. Once ground water has been contaminated, long term cleanup and the difficulties which pertain thereto are unavoidable.

There are other areas in the Santa Ana Region where high nitrate levels have been detected in the ground water. In some of these areas, such as Corona and the Bunker Hill Basin, high nitrate water has to be blended with good quality water before distribution. The Orange County Water District has undertaken a multimillion dollar well-head treatment project for wells in the Orange County basin with high nitrate levels and is exploring the feasibility of in-situ biological denitrification.

Extensive efforts are underway by Regional Board staff, the Santa Ana Watershed Project Authority, the Santa Ana River Dischargers Association and about a dozen other agencies and municipalities to address surface and ground water quality problems in the Region which are related to nitrogen. A one million dollar study funded cooperatively by these parties is in progress.

A primary objective of this study is to develop recommended limitations on nitrogen discharges from sewage treatment plants to protect both ground and surface waters. Measures needed to address nitrogen problems related to past and present agricultural activities, including dairies, are also being evaluated. The results of this study will be used in conjunction with other ongoing Basin Plan update activities to develop an optimal water quality management plan.

In light of these efforts, Board staff would be remiss not to address the significant nitrate contamination problem in the Fontana and Bloomington areas. Given the conditions previously described (soil conditions, lack of dilution by precipitation and ground water flow, high density developments, etc.), water quality degradation is virtually assured unless the septic system density is controlled or other control measures are implemented.

III. Public Health and Septic Systems

A. General Impacts

It is reported that septage or sewage, primarily from septic tanks or cesspools, is responsible for 45 percent of disease outbreaks and 66 percent of disease caused by contaminated surface and ground water in the United States. Septic tank leachate is the most frequently reported cause of ground water contamination.

The consumption of contaminated ground water can result in various types of illness. A more detailed look at ground water contaminants and their potential impacts on public health will demonstrate the serious responsibilities inherent in septic system regulation.

B. Inorganic Ion Contaminants (Nitrate)

Nitrogen and phosphorus are the major mineral constituents causing water quality degradation. Of these, nitrogen in the form of nitrates is generally the first contaminant associated with septic system effluent to exceed public health standards. As discussed earlier, nitrates often receive very little treatment or denitrification due to the characteristics of soils in the study area and their rapid movement through soils. This results in nitrate accumulation in ground water. If these accumulations go undetected for long enough periods of time, nitrate concentrations can exceed the generally accepted criterion of 10 mg/l as N (or 45 mg/l as NO_3) and can thereby pose a threat to public health. This most often takes the form of methemoglobinemia, more commonly known as the "blue baby syndrome". As the latter term implies, methemoglobinemia symptoms are seen in babies under four to six months of age.

Less well known are the recent studies linking nitrates to cancer. A recent study in Nebraska linked increased levels of nitrates in ground water to an increased incidence of leukemia and lymphoma. In addition, regional studies in Italy by local universities and multinational studies in Europe by Johns Hopkins University staff have produced epidemiological evidence of a positive correlation between increased levels of drinking water nitrates and an increased incidence of gastric cancer. This is further supported by a 500 page report by the National Academy of Sciences on the health effects of nitrates, nitrites, and N-nitroso compounds, which states that nitrates can be chemically reduced to nitrites not only in infants (leading to methemoglobinemia), but also in adults, especially those adults with high stomach acidity. The significance of this finding is that nitrates are capable of combining with amines within the stomach at high acidity to form nitrosamines - one of the most potent carcinogens known to man. It may be this mechanism which leads to the higher observed incidence of gastric cancer in those population groups included in the epidemiological studies.

C. Heavy Metals, Pesticides, Solvents, and Fuels

These pollutants can be discharged from family septic systems and, especially, from light industrial and commercial septic systems. These substances are not treated as they move through septic systems and, consequently, they can contribute to the contamination of ground water. Although it has not been documented that any of these pollutants cause ground water problems in the study area, the regulation of high density septic systems in the area will alleviate Board staff's concern about their potential adverse impacts on local ground water.

D. Pathogens

Contamination of ground water by pathogens (disease causing organisms) is the most frequent cause of waterborne illness in the United States. Such pathogens include bacteria and viruses. The literature contains many reports of disease outbreaks attributable to ground water contaminated by septic system effluent and the pathogenic organisms it carries. However, if sufficient filtration of pathogens occurs through the soil strata, the threat from pathogens is not significant. In the study area, pathogens are almost completely removed from the septic tank effluent due to the depth of ground water which is generally greater than 400 feet.

In summary, the potential for ground water contamination and adverse public health effects associated with septic systems extends beyond nitrates and can include such significant constituents as heavy metals, synthetic organic compounds and pathogens. No simple solutions to the problem of ground water contamination via septic systems exist. At this time the most widely recognized method of protecting ground water quality against public health threats is the regulation of septic system densities through minimum lot size requirements.

IV. Control Measures

As discussed in preceding sections of this report, studies conducted throughout the nation have established a definite link between ground water contamination and the use of septic tank systems for wastewater disposal. The soil conditions in the study area are such that the migration of nitrate and other contaminants from septic systems into the ground water is facilitated. To control this contaminant migration, wastewater discharges to septic systems need to be controlled. The control options include the following:

A. Technological Approach

The constituent of immediate concern to Board staff, in terms of water quality degradation, is nitrogen. As previously discussed, most of the nitrogen constituents in septic system effluent are converted to nitrate in the well-aerated soils of the study area. In the study area, nitrate migrates through the soil essentially unaffected, and reaches the ground water. However, the nitrified effluent could be denitrified using a variety of technologies such as dosing/no-dosing cycles, passive Ruck systems, recirculating sand filter systems, etc. For individual septic tank systems, this approach is neither economically feasible nor viable. Effective and reliable maintenance and operation of these systems by individual homeowners or homeowners association are too expensive.

B. Regulatory Approaches

1. Waste Discharge Prohibition

Adoption of a waste discharge prohibition on the use of septic systems requires the Regional Board to document and substantiate serious public health and water quality problems resulting from septic systems. Alternatives to septic system use must be identified and their feasibility and affordability must be considered. Within the Santa Ana Region there are several waste discharge prohibition areas. These prohibitions were adopted primarily on the basis of immediate public health concerns caused by surfacing effluent. There were also important concerns about ground water contamination in many of these areas, but insufficient data was available to provide documentation of this problem. Similarly, in the Fontana/Bloomington area, it may take several years to document nitrate problems resulting from septic systems. At that point, it may be too late to correct the problems.

2. Extension of Sewer by the Developer

Requirements on developers to extend sewer lines to new or existing developments may be an option available to some of the local agencies. The City of Redlands requires the developer to extend the sewer line by 100 feet for each dwelling unit built in an unsewered area. The City of Fontana has a partial reimbursement program whereby the City uses sewer assessment fees to reimburse developers part of the cost of extending the sewer. Developers have generally attempted to avoid this program, largely because septic systems are cheaper.

3. Building Moratorium by Local Agencies

To date, there is no building moratorium in the area. Impetus for such a moratorium could be provided by the water quality concerns described in this report. It is unlikely, however, that local agencies would take unilateral action to stop developments utilizing septic systems.

4. Restrict the Lot Size

Staff's fundamental concern with septic systems in the study area is the cumulative water quality impact (both spatially and over time) of the use of large numbers of these systems in high density. In many instances, ground water problems could be avoided by the proper construction, installation, and maintenance of septic systems. However, the most important factor influencing ground water contamination from onsite waste disposal systems is the density of systems in an area. The potential impacts to ground water quality have already been discussed. Direct or indirect discharges of septic system effluent and its constituents to surface waters may also occur.

The potential cumulative impacts of high density septic systems are twofold. First, many substances contained in sewage are soluble and may move relatively unaffected through the soil to accumulate in underlying ground water (discharges to adjacent surface waters can also occur). Second, under certain conditions, the total volume of wastewater discharged from a large number of systems may alter local ground water levels to the point that the performance of individual systems, or the degree of treatment provided by the soil system, is adversely affected.

Again, while a number of factors (soil conditions, depth to ground water and climate) affect the nature and degree of the contamination problem caused by septic systems, the density of the systems is the principal controlling factor. As lot size increases (and densities thereby decline) ground water contamination problems decline since more ground water is available for dilution of the septic tank effluent percolating into the aquifer.

Using the following equation, it is possible to estimate the critical development density (D_c), defined as the acre/dwelling unit ratio, that will result in an areawide percolate nitrate nitrogen concentration of 10 mg/l (45 mg/l as nitrate - drinking water standard).

$$D_c = \frac{(2.01)(N_p - 10)}{(DP)(10 - N_b)}$$ [Hantzche, N. N. -1986 (3)]

Where:

D_c = Critical Development Density; acre/edu (equivalent dwellingunit)

N_p = Wastewater nitrate nitrogen concentration (mg/l); 40 mg/l (assumed)

N_b = Background nitrate nitrogen concentration of percolating rainfall (mg/l); 0.5 mg/l (assumed)

DP = Deep percolation of rainfall (in/yr); 12 in/yr (assumed)

2.01 = Conversion factor for assumption of the discharge rate of 150 gallons per day/edu

Therefore:

$$D_c = \frac{2.01(40 - 10)}{12(10 - 0.5)}$$

$$= 0.53 \text{ acres/edu}$$

The value of 12 in/yr for deep percolation of rainfall assumed in this calculation is probably unrealistic; using a more realistic figure (3.72 in/yr) yields the following result for the study area:

$$D_c = \frac{2.01(40 - 10)}{3.72(10 - 0.5)}$$

$$= 1.71 \text{ acres/edu}$$

Based on these calculations, septic system densities of 0.53 to 1.71 acres/edu should not result in violation of the primary drinking water standard for nitrate in ground water. Currently, the average density of developments on septic systems in the study area is 0.17 acres/edu.

5. Treatment of Wastewater Using Package Treatment Plants

This option is not favored by Board staff due to the fact that the reliability of the operation and maintenance of a package sewage treatment plant, if not closely regulated, is questionable. However, some developers have been willing to construct the treatment plants for their projects.

V. Action Taken by Other Regulatory Agencies

A. Regional Boards

The Santa Ana Regional Board has established waste discharge in several areas primarily due to failing septic systems. As stated previously, ground water contamination problems were also a concern (e.g. the Yucaipa-Calimesa area). Three other regional boards have amended their Basin Plans to include density requirements for septic systems. Region 1 (North Coast Region) adopted acreage requirements ranging up to 20 acres. Region 3 (Central Coast Region) adopted a Basin Plan amendment in 1982, stating a preferred minimum acreage of one acre, yet allowing, under especially well-suited conditions, a one-half acre lot size. Region 6 (Lahontan Region) adopted a Basin Plan amendment specifying a minimum lot size of one-half acre per edu. Other regional boards delegate decisions on minimum lot size requirements for septic systems to local regulatory agencies.

Region 5 (Central Valley Region) adopted a Basin Plan amendment in 1988, prohibiting the discharge of wastes from individual septic systems within the Chico urban area due to high nitrate problems in local ground water.

B. Counties

The majority of California counties already have their own septic system density requirements. Seventy-eight percent of the 54 counties with these requirements require a lot size greater than or equal to one-half acre when an on-site water source is used. Even when an outside source of water is employed, 46 percent of the 54 counties require a lot size greater than or equal to one-half an acre. There is a clear trend towards tightening these requirements.

Those counties without septic system density requirements generally include heavily urbanized, sewered areas or rural areas where septic system densities and their impacts on water quality have not presented major problems.

RECOMMENDATION:

Regional Board staff believes that careful review of the various options available to address septic system disposal practices in the Fontana and Bloomington area is warranted. In reviewing these options, staff will consider the comments received in response to this staff report and at the Public Workshop on April 14, 1989. A staff recommendation will be presented to the Board at a future Board meeting.

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